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THIRTEENTH FOURTEENTH AND FIFTEENTH ANNUAL REPORTS

OF THE

RESEARCH COUNCIL OF ALBERTA

1932 1933 1934

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The Research Council of Alberta, formerly known as The Scientific and Industrial Research Council of Alberta, was formed in January, 1921. It was incorporated under its new name by an act of the Legislature of the Province of Alberta March 21st, 1930.

No separate vote of funds for the Council was made by the Legislature in 1933, but arrangements were made by which the University of Alberta took over the senior members of the staff and provided for the continuation of some sections of the work. A skeleton organization has thus been preserved which may be readily expanded when funds are again available.

The personnel of the Council at the time its duties lapsed was as follows:

J. E. Brownlee, Premier of Alberta, Chairman.

R. G. Reid, Minister of Lands and Mines.

O. L. McPherson, Minister of Public Works.

R. C. Wallace, President, University of Alberta, Director of Research.

R. S. L. Wilson, Dean, Faculty of Applied Science, University of Alberta.

G. A. Vissac, Esq., Blairmore.

J. I. McFarlane, Esq., Calgary.

R. J. Dinning, Esq., Edmonton.

Secretary, A. E. Cameron, University of Alberta.

Technical Advisors (meeting with Council)

Prof. J. A. Allan—Geology.

Prof. N. C. Pitcher—Mining Engineering.

Prof. E. Stansfield—Chemical Engineering.

The work of the Council is carried out in the University of Alberta. Requests for information and reports should be addressed to the Secretary, Research Council of Alberta, University of Alberta, Edmonton, Canada.

TABLE OF CONTENTS

THIRTEENTH, FOURTEENTH AND FIFTEENTH ANNUAL REPORTS OF THE RESEARCH COUNCIL OF ALBERTA

INTRODUCTION.

Annual Reports of the Council, from 1920 to 1931 inclusive, were prepared shortly after the close of each year, submitted to the Provincial Legislature, and then published. The Reports for 1932, 1933 and 1934 respectively were prepared as usual each year, and submitted to the Legislature by The Director of Research, but no funds were available for their publication. It has now been found possible to publish the three reports in one volume.

The reports, as submitted to the Legislature, have been slightly curtailed for printing, but on the other hand advantage has been taken of the delay in publication to bring up to date certain statistics, etc., as noted. The paging is continuous through the volume, and the tables of contents of all three reports have been brought to the front for convenience of reference. In other respects each annual report is printed as a separate report and follows the general plan of previous annual reports.

Organization.

In the organization of the Provincial Government the Research Council was attached to the Department of the Executive Council. The Research Council, until March 31st, 1933, controlled the policies of research and administered the funds voted by the Legislature. Since that date the work, notably reduced in extent, has been controlled and financed through the University of Alberta.

The Director of Research, Dr. R. C. Wallace, President of the University of Alberta, is in executive charge of the work and is assisted by a technical advisory committee consisting of the following members:

President R. C. Wallace, Chairman.
Dean R. S. L. Wilson, Vice-Chairman.

J. A. Allan,	R. L. Rutherford,
E. H. Boomer,	J. W. Shipley,
K. A. Clark,	E. Stansfield,
H. J. Macleod,	F. A. Wyatt,
N. C. Pitcher,	A. E. Cameron, Secretary.

The offices and laboratories of the Council are situated in the buildings of the University of Alberta.

Staff.

The permanent staff of the Research Council through the three years covered in these reports was as follows:

E. Stansfield, Chief Chemical Engineer;
K. A. Clark, Research Engineer, Road Materials;
R. L. Rutherford, Geologist, Geology;
W. A. Lang, Engineer, Fuels;
K. C. Gilbart, Engineer, Fuels;
Hazel M. Wortman, Stenographer.

In addition to the above, members of the Faculty of the University of Alberta have been in permanent charge of sections of the Council's research work as follows: Dr. J. A. Allan, Geology; Professor N. C. Pitcher, Mining Engineering; Dr. F. A. Wyatt, Soil Survey; and Dr. E. H. Boomer, Natural Gas and Hydrogenation. Dr. A. E. Cameron has acted as secretary to the Council.

THE UNIVERSITY OF ALBERTA, EDMONTON,
August, 1935.

Report No. 28.

THIRTEENTH ANNUAL REPORT

OF THE

RESEARCH COUNCIL OF ALBERTA

1932

University of Alberta
Edmonton Alberta

THIRTEENTH ANNUAL REPORT OF THE RESEARCH COUNCIL OF ALBERTA

FUELS.

The main work of the year was the completion of the detailed examination of the coal survey across central Alberta commenced late in 1931. The Dominion Department of Mines and Provincial Mines Branch assisted. Eighteen coals were included in this survey, which extended from Nordegg on the west to Castor and Sheerness on the east.

The one cycle accelerated weathering test developed by the U.S. Bureau of Mines to indicate slacking character of coals has been applied to 34 typical coals of the Province. Also a method has been developed for testing the friability of coal, which will act as an indication of its handling properties. This work was done in cooperation with a committee of the American Society for Testing Materials.

The fusibility of the ash of coal is of increasing importance in industrial use of coal, and the procedure has been further improved with the use of a gas-fired, surface combustion, muffle furnace to determine the fusibility of the ash of the various types of the coals of the Province. During the year some 20 ash samples were examined in this way.

Other investigations included further tests on the solubility of coals in organic solvents and on the ignition temperature of coals.

The information obtained from analytical work on coals has been compiled up to date, and this information studied with special reference to the classification of coals. This latter work has been carried on in cooperation with a committee of the National Research Council and is financially assisted by that Council.

A fuller account of this work is given in the report of the Fuels Division.

GEOLOGY.

The work of the Geological Division of the Council is directed by J. A. Allan in conjunction with the Department of Geology at the University of Alberta. R. L. Rutherford assists in teaching in the Department and in return P. S. Warren determines all palaeontological material received by the Research Council.

R. L. Rutherford spent the greater part of two months on field work. Some of the results of his field work are given in the report of the Geology Division. He also spent some time in the office compiling data obtained previously in the field.

J. A. Allan conducted the office duties and compiled statistical data on the entire mineral production in Alberta since 1878. He also made an examination into the stability of Turtle Mountain at Frank, Alberta. Summaries of his work are given in the report.

Details on the progress in the Geological Survey Division in 1932 are given in a later part of the Report.

ROAD MATERIALS.

The Road Materials Division has continued its investigation of the physical chemical foundation underlying the bituminous sand extraction process developed in previous years. The results indicate a great simplification of the separation process and equipment. They are also likely to have significance in a broader field. The same factors can be manipulated to accomplish entirely different purposes, as for example, in the stabilizing or improving of weather resisting properties of bituminous road aggregates.

SOIL SURVEYS.

No soil surveys were carried out under the auspices of the Council during 1932, but the services of Mr. J. L. Doughty were retained by the Department of Lands and Mines for special soil classification work.

NATURAL GAS RESEARCH.

Pyrolysis experiments carried on in Calgary to study possible utilization of the Turner Valley waste gas were brought to completion. The results obtained indicate that treatment of waste gas as such is not likely to prove profitable, but work done on stabilizer gas showed that very satisfactory results could be obtained from that material.

Operation of the Pyrolysis laboratory has shown that from 2½ to 3 gallons of oil, which is largely benzene, may be obtained from 1,000 cu. ft. of stabilizer gas, together with from 1½ to 2 gallons of tar, carrying about 35% napthalene.

Other work has included hydrogenation tests on bitumen from the bituminous sands of the Athabaska river, on coal and on cellulosic materials, such as wood sawdust and cotton. It has been shown that hydrogenation of the bitumen gives satisfactory results, and that the successful hydrogenation of coal is largely a problem of the mineral matter content of the coal. The work on cellulosic materials has shown that by the use of tetralin as a hydrogenating medium these materials can be completely reduced to oil. These latter results when applied to wheat screenings, largely wheat seeds, chaff and wheat, did not produce promising results.

ACKNOWLEDGMENTS.

Appreciation is expressed to the Dominion Department of Mines and to the Provincial Mines Branch for cooperation and assistance in the coal survey in central Alberta, and to the National Research Council for financial assistance with the work on coal.

Appreciation is also expressed to the Principal and members of staff of the Provincial Institute of Technology and Art at Calgary for laboratory accommodation and facilities, and to the Imperial Oil Company and other producers in the Turney Valley field for assistance in the natural gas research.

PUBLICATIONS BY MEMBERS OF THE STAFF.

"Donaldson Bogart Dowling": Biographical sketch to D. B. Dowling Memorial Symposium, "Stratigraphy of Plains of Southern Alberta," by J. A. Allan. Bull. American Association of Petroleum Geologists, Vol. 15, No. 10, 1931.

"Determination of the Alkali-Soluble Ulmins in Coal," by E. Stansfield and K. C. Gilbart. Trans. A.I.M. & M.E., Coal Division, 1932.

"Moisture Determination for Coal Classification," by E. Stansfield and K. C. Gilbart. Trans. A.I.M. & M.E., Coal Division, 1932.

"The Drying of Wheat," by E. Stansfield and W. H. Cook. Report No. 25 of the National Research Council, covering an investigation under the Associate Committee on Grain Research of the National Research Council, was published during the year.

"An Occurrence of Pickeringite in Alberta," by R. L. Rutherford. American Mineralogist, Vol. 17, August, 1932, p. 401.

"The Stratigraphical Horizon of Laosaurus Minimus," by J. A. Allan and R. L. Rutherford. American Jour. of Science, Vol. XXIV, September, 1932, p. 225.

"Future Mineral Development in Alberta," by J. A. Allan. Engineering Journal, October, 1932.

"Hot Water Separation of Bitumen from Alberta Bituminous Sand," by K. A. Clark and D. S. Pasternack. Ind. and Eng. Chem. Vol. 24, December, 1932, p. 1410.

"Reactions of Ethyl Alcohol on Nickel-Chromium Catalysts," by E. H. Boomer and H. E. Morris. Canadian Jour. of Research 6:471-484, 1932.

ROBERT C. WALLACE, *Director of Research,*

University of Alberta, Edmonton.

February 14th, 1933.

FUELS DIVISION

BY E. STANSFIELD, W. A. LANG, K. C. GILBART, R. G. BREWER AND H. E. MORRIS.

The staff of this Division was seriously reduced during the year, and the work accomplished was necessarily curtailed. The National Research Council showed their appreciation of the importance of the work in progress by arranging for K. C. Gilbart to continue work for the remainder of the year at their expense.

SAMPLES RECEIVED.

A larger number of coal mine samples were analysed this year than in recent years, although many of the special tests were necessarily omitted. Provincial Mine Inspectors submitted 67 channel samples from operating mines; they also supplied 34 samples for weathering tests, 5 samples of glossy coal (anthraxylon) for microscopic examination in Germany, and transmitted 5 samples from Operators for analysis. Additional samples received included: 1 large and 2 small samples from Operators for special tests; 7 samples of coal from bore holes; 2 samples of coal from the lignite deposits at Great Bear lake. Samples were received from 15 mines not previously sampled. Coal mine samples have now been analysed from some 135 separate townships, a good indication of the area of the Province in which active mining has occurred.

Samples other than coal included one mine dust sample, and 23 samples of grain, seeds, etc.

SAMPLING AND ANALYSIS.

The development of the work on the moisture holding capacity of coal has rendered advantageous certain modifications in laboratory procedure. Coal has been air-dried in the past to fulfil two requirements, first to determine the moisture holding property of the coal, and second to bring the sample to a condition in which it will not rapidly lose or gain moisture when exposed during weighing. The standard conditions for the first requirement were often not satisfactory for the second. It is now feasible to determine, on a small portion of the sample, the moisture retained at 86°F and 60% relative humidity, the standard conditions employed, and to air-dry the main sample to best suit the second requirement. This involves no notable change in the reported results.

A second development of the above work is the ready determination of the "true" or "capacity" moisture of the coal. The moisture retained by a small sample when dried in vacuo at 86°F and 97% relative humidity has been found to average close to 99% of the true moisture. The total moisture in all samples is determined as before, but the true moisture is also determined: so that when a sample is received from a wet spot in a mine the extraneous moisture is clearly indicated. The same tests also indicate when the coal contains less moisture than its holding capacity. A mine district was liable to be adversely affected by inclusion of the analyses of wet samples when average values were being computed. In future this difficulty should be overcome.

Comparison analyses on six samples of coal were made in 1931 in the fuel testing laboratories at Ottawa and Edmonton, and in certain commercial laboratories. A further investigation of this nature was made in 1932. Inspectors of the Provincial Mines Branch took samples from six mines in the Drumheller

Area and portions of each sample were distributed to Ottawa, Montreal, Edmonton and other laboratories. The work has been completed at Edmonton, and reported, but the compilation of reports has not yet been received.

MOISTURE IN COAL.

In the 1931 Report a method was mentioned for determining the moisture retained by coal when dried in vacuo at 30°C at varying relative humidities (variations in vapour pressure with moisture content). This method has been employed during the year with 73 coal samples. With 43 of these sufficient values were obtained to prepare full curves representative of zero to 100% humidity; with 30 samples one or two points only were determined.

Samples of Edmonton coal were steam treated for two hours in an autoclave at pressures of up to 300 lbs. per sq. in., but the moisture holding capacity of the coal was only slightly reduced. This work was commenced in connection with a study of the economic possibilities of drying the higher moisture Alberta coals by the Fleissner method with high pressure, saturated steam.

CENTRAL ALBERTA COAL SURVEY.

A detailed coal survey across the south of the Province was commenced in 1930 and completed in 1931. A similar coal survey across Central Alberta was commenced late in 1931 and continued in 1932. The Dominion Department of Mines and the Provincial Mines Branch assisted. The districts covered included Nordegg, Saunders, Big Valley, Three Hills, Carbon, Drumheller, Wayne, East Coulee, Castor and Sheerness. Both surveys have now been completed although it is still hoped to do a little more work on the solubility of the coals in organic solvents, and some hydrogenation tests on the coals of the latter survey.

Complete proximate and ultimate analyses were made on a regular channel sample as well as on a selected sample from each mine. These have been reported to the Operators concerned.

Each selected sample of coal was divided into five or more fractions with different ash percentages, and a complete proximate, ultimate and calorific value analysis made of each fraction. The results for each constituent were plotted against the corresponding ash percentage, and, from the resulting curves it was possible to deduce the correct and full analysis of the pure coal substance. These analyses of the pure coal are given in the following table, together with the results of a number of physical tests. The coals, marked A and B, are arranged in order of descending fixed carbon content in the coal, moist as mined. The subsequent coals, C to V, are arranged in order of descending calorific value on the same basis. It can be noted that this order is approximately the order of increasing distance of the mines from the eastern face of the Rocky Mountain range.

The Fuel Testing Division of the Mines Branch at Ottawa has carried out low temperature carbonisation tests on the coals of both surveys, and has reported the results to the Operators.

SLACKING CHARACTER AND FRIABILITY OF COAL.

Tests on slacking character were made as during 1931 with the one-cycle "accelerated weathering test" developed by the U.S. Bureau of Mines. In this test coal lumps are air dried, soaked in water, redried, screened, and the loss

TABLE I.

COAL SURVEY—TYPICAL CENTRAL ALBERTA COALS

Coal	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	V
Geological horizon (1)	K	K	B	B	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Approximate distance of mine east of mountain face—miles	0	0	5	5	80	85	95	100	100	105	100	105	105	115	140	140	145	155
Proximate analysis of pure coal, moist as mined:																		
Fixed Carbon %	81.7	80.5	52.3	53.7	49.6	51.1	49.1	48.0	47.4	47.2	46.7	47.5	47.2	45.6	40.0	40.4	39.5	39.1
Volatile Matter %	17.0	18.3	37.3	35.1	34.2	31.6	31.4	32.2	33.1	32.8	31.8	31.4	31.4	30.8	31.2	30.6	30.9	29.9
Moisture %	1.3	1.2	10.4	11.2	16.2	17.3	19.5	19.8	19.5	20.0	21.5	21.1	21.4	23.6	28.8	29.0	29.6	31.0
Proximate analysis of pure, dry coal:																		
Fixed Carbon %	82.8	81.5	58.4	60.5	59.2	62.2	61.0	59.9	58.9	59.0	59.5	60.1	60.0	59.7	56.2	56.9	56.2	56.7
Volatile Matter %	17.2	18.5	41.6	39.5	40.8	37.8	39.0	40.1	41.1	41.0	40.5	39.9	40.0	40.3	43.8	43.1	43.8	43.3
Ultimate analysis, pure, dry coal:																		
Carbon %	90.30	90.50	79.40	80.26	75.50	77.15	76.75	76.00	76.60	75.49	75.60	75.44	....	76.30	....	73.10	73.35	....
Hydrogen %	4.64	4.76	5.42	5.29	5.22	5.02	5.09	4.90	5.10	5.11	5.04	5.03	....	5.25	....	4.78	5.07	....
Oxygen %	3.17	2.76	13,51	13.00	17.50	16.10	15.90	16.80	15.84	17.00	16.93	17.30	....	17.00	....	20.30	19.70	....
Nitrogen %	1.40	1.40	1.27	1.20	1.38	1.27	1.80	1.70	1.76	1.78	1.77	1.63	....	1.15	....	1.52	1.30	....
Sulphur %	0.49	1.58	0.40	0.25	0.40	0.46	0.46	0.60	0.70	0.62	0.66	0.60	....	0.30	....	0.30	0.58	....
Calorific Value of pure coal:																		
Moist, B.t.u./lb.	15,710	15,720	12,720	12,570	11,250	11,060	10,850	10,770	10,750	10,510	10,440	10,420	10,280	9,860	9,090	8,910	8,770	8,560
Dry, B.t.u./lb.	15,920	15,910	14,200	14,160	13,430	13,370	13,480	13,430	13,350	13,140	13,300	13,210	13,080	12,910	12,760	12,550	12,450	12,400
Fuel ratio	4.80	4.41	1.40	1.53	1.45	1.62	1.56	1.49	1.43	1.44	1.47	1.51	1.50	1.48	1.28	1.32	1.28	1.31
Solubility of pure, dry coal in caustic potash %	0.0	0.0	2.9	2.0	14.4	17.5	14.7	19.2	12.2	16.3	15.5	14.7	23.5	40.6	39.2	24.8	43.5	39.7
Specific gravity of coal with 8% ash and moist as mined	1.34	1.34	1.36	1.36	1.35	1.36	1.34	1.35	1.35	1.35	1.35	1.35	....	1.35	1.33	1.34	1.34	1.32
Ignition temperature of dry coal °F	440	442	361	368	355	353	354	355	349	347	353	356	354	359	347	346	369	359
Weathering loss, one cycle %	3	0	5	3	41	62	26	49	21	40	44	70	....	85	77	92	87	66
Strength index	11	18	55	42	58	43	65	58	70	60	58	49	....	61	....	68	78	81
Softening temperature of ash °F	+2,600	+2,600	2,055	2,080	2,100	2,310	1,960	1,970	1,960	1,920	2,235	1,960	2,040	2,460	2,040	2,030	2,325	2,050

(1) K:Kootenay; B:Belly River; and E:Edmonton horizons.

through the screen determined. Increasing use is being made of this test in America to evaluate the rank of coals and some 34 selected typical coals were tested during the latter part of the year. Some earlier tests on slacking were made before the test was standardized in its present form. All the results obtained have been compiled, and an effort made to compute the earlier tests to a comparable basis with the later work. Many more samples should be tested.

A quick method was developed for testing the friability of coal. Small lumps of coal are placed in a box which is slowly rotated, and the revolutions counted. Each revolution the lumps are picked up by a baffle and allowed to drop onto an iron plate. The coal then slides over a screen and the fines produced fall out onto the pan of a balance. The test is stopped as soon as a definite percentage (say 20% by weight) has been collected on the balance. No routine tests have been made, but the method showed satisfactory agreement in duplicate runs. The work was done in cooperation with a committee of the American Society for Testing Materials.

Solubility of Coal in Organic Solvents.

Extraction tests on 4 large samples, 250 grams, were made in a Cook autoclave. These extractions required up to 400 hours each and the work had to be dropped for financial reasons. The autoclave is electrically heated; automatic controls were installed during the year.

Small scale tests were made on 5 different coals. Each coal was extracted, in duplicate, in 3 or 4 different solvents. Work was also conducted to show the effect of oxidation of the coal on its solubility.

Considerable difficulty was encountered in this work owing to the expansion of the coal during extraction and the consequeqnt fracture of the paper, glass or alundum containers. It was found that if the weighed sample of the dried coal was soaked in the solvent, for some hours, prior to placing it in the container this difficulty was entirely overcome.

Ignition Temperature of Coal.

Determinations of this temperature have so far been made by the Wheeler method. The method, however, has not been found entirely satisfactory and efforts to improve it were unsuccessful. The method, moreover, gives values of academic rather than practical significance as the temperature recorded is that at which finely powdered coal, in a current of oxygen, begins to rapidly rise in temperature. A new apparatus has been constructed for determining the minimum temperature at which coal, in a current of air, will rapidly ignite. The test has not yet been developed to completion, but present indications are encouraging.

Coal Classification.

Compilation of the analytical work on coals has been brought up to date, and studies of these values are in progress with especial reference to the classification of coal. This work is carried on in cooperation with a committee of the National Research Council and is financially assisted by that Council.

Miscellaneous Investigations.

The Division has been consulted by the Fire Commissioner's Department and by the Fire Underwriters Investigation Bureau. In connection with this an experiment was made as to the behaviour of a large cheese exposed to fire. The heat value of the cheese was also determined. It was found to be about 9,200 B.t.u./lb.

Five samples of glossy coal (anthraxylon) were obtained by request for microscopic examination by a coal petrographer in Germany. These were analysed before being shipped. The small, carefully selected samples were lower in ash than average samples from the same mine. The heat values were approximately as would be expected, but the volatile matter appeared relatively lower than in similar samples of average coal.

Queries have from time to time been received as to the values of certain grains, etc., as fuels. The Dominion Grain Research Laboratories kindly supplied a number of samples on which they had determined the moisture content. Twelve samples were tested for their heat values. These are as below, computed to a common moisture content of 10%. The heat values may be compared with a heat value of 8,700 B.t.u. for typical Edmonton coal as mined.

TABLE II.

CALORIFIC VALUE OF GRAIN

Grain.	Calorific Value, Gross B.t.u./lb., calculated to basis of 10% moisture in sample.
Wheat average 1 hard	7,370
Wheat average 6 hard	7,380
Wheat average 1 C.W. Amber Durum	7,400
Barley 3, Extra 6 row	7,320
Barley 6, C.W.	7,360
Oats 2, C.W.	7,760
Oats, mixed feed	7,770
Oats, wild	7,760
Refuse screenings	7,500
No. 2 Feed screenings	7,460
Weed seeds	8,240
Bran	7,690

GEOLOGICAL SURVEY DIVISION

By J. A. Allan and R. L. Rutherford.

Reduced appropriations necessitated discontinuance of field parties for the year. R. L. Rutherford spent almost two months (part of the time alone), in the field continuing the investigations started two years ago between Edmonton and Athabaska river. This season the work was extended east of Athabaska river to the La Biche area then southward to North Saskatchewan river. Geological details in this part of the Province were not known and it was necessary to obtain data in this area in order to interpret the geology of central and northern Alberta. Much valuable stratigraphical and structural information has been obtained in connecting the geology along the North Saskatchewan with that along the Athabaska and Peace rivers. This geological information should ultimately prove valuable in future mineral development in northern Alberta. Water resources and gravel deposits were investigated in this area and at other scattered localities in Alberta. A summary report of the work is given below.

R. L. Rutherford spent some time during the summer in compiling data he had previously obtained in the Peace river country, particularly north of Peace river.

Office duties have been carried on throughout the year, but the service offered to enquirers has of necessity been curtailed.

Continued requests, some of which have been pathetic, have been received from farmers in different parts of Alberta for assistance in obtaining a water supply sufficient for their needs. Assistance was rendered when the information was available, but some of the requests come from areas where exact information on water supply is not on hand, and these enquirers could not be assisted.

A large number of requests have been received on gold placer possibilities in Alberta, but remarkably little data is available on the gravels along several rivers where gold is known to occur. Requests on the best methods of prospecting placer gravels have been adequately attended to by Professor N. C. Pitcher. A circular, outlining possible prospecting ground for placer gold and a discussion of methods of recovery, is a service that could be given at a small cost to those endeavouring to obtain a livelihood from placer mining.

Assistance in geological matters has been given to Mr. Wm. Calder, Director, Petroleum and Natural Gas Division of the Department of Lands and Mines, and considerable geological data on well logs have been received from his office.

During the first two months mineral production statistics were studied and compiled in graphical form. A few notes on these results are given in this report.

Water supply data on about twenty wells in the Lacombe and Gull Lake districts were obtained during the summer without cost to the Division.

A request was received from Mr. O. L. McPherson, Minister of Public Works, to investigate stability conditions in Turtle mountain, at Frank, in the Crowsnest District, and to determine if possible the danger from any large scale rock slide such as occurred in 1903. The first field study was made in

October, 1931, and a report by J. A. Allan was submitted in December of the same year.

A second visit was made at the request of the Minister of Public Works in September, 1932, and the report on this investigation has been presented under special cover. Summary notes on this work are given below.

TURTLE MOUNTAIN ROCKSLIDE.

(J. A. Allan)

On April 29, 1903, at 4:10 a.m. the great rock slide at Frank occurred. Approximately 90,800,000 cubic yards of rock slid down from the east face of Turtle mountain and cascaded across the valley for a distance of two and a half miles in less than two minutes. Seventy lives were lost and part of the town of Frank was covered up as well as 7,000 feet of the Canadian Pacific Railway grade.

On recommendation of a Commission in 1911 part of the remaining town was removed by the Dominion Government to safer points.

An uneasiness of nearby residents became apparent in 1931, and the Provincial Government took immediate steps to investigate. As a result the first report on instability conditions was presented in December, 1931. A second examination was made in September, 1932.

MINERAL PRODUCTION IN ALBERTA, 1887-1934.*

(J. A. Allan)

Mineral production in the territory now represented by Alberta began about 1887 according to Government records. Table I gives the values of each mineral or mineral product produced in Alberta for each year since 1887, and also the total value of minerals produced in Alberta since 1887. A comparison is also given with the total production in Canada for the same period. These mineral statistics have been compiled from Dominion Government records, and care has been taken to record the correct values. This table and also the graphical tables may be taken in future considerations on the mineral development within the Province of Alberta.

Up to date, that is between 1887 and 1934, inclusive, there have been produced in Alberta minerals to the value of $580,569,634. This represents 9.6 per cent. of the mineral production from the whole of Canada for the same period.

In 1887 Alberta produced gold to the value of $2,100 and coal to the value of $157,577. The total value in that year from Alberta represented 1.5 per cent. of the total mineral value for Canada. In 1931 Alberta produced minerals to the value of $23,580,901, or 10.3 per cent. of the total minerals produced in Canada. Natural gas revenue was first recorded in 1898; clay products and lime in 1906; sand and gravel in 1908; stone in 1909; cement in 1910; petroleum in 1914; bituminous sand in 1924; and salt in 1925.

A summary of the mineral production values recorded from Alberta between 1887 and 1934 is given as Table II.

*Due to the delay in the publication of this report the mineral statistics for the years 1932, 1933, and 1934 have been added to Tables I and II, and also to the graphical tables.

TABLE I.—TOTAL VALUE IN DOLLARS—MINERAL PRODUCTION OF ALBERTA, 1887-1934 COMPARED WITH CANADA PRODUCTION.

Year	Gold	Coal	Natural Gas	Petroleum	Clay Products	Salt	Bitu. Sand	Cement	Lime	Sand & Gravel	Stone	Other Products	Total for ALBERTA	% of Canada Total	Total for Canada	Year
1887	2,100	157,577											159,677	1.5	10,321.331	1887
1888	1,200	183,354											184,554	1.4	12,518.894	1888
1889	20,000	179,640											199,640	1.4	14,013.113	1889
1890	4,000	198,298											202,298	1.2	16,763,353	1890
1891	5,500	437,243											442,743	2.3	18,976,616	1891
1892	10,506	460,605											471,111	2.8	16,623,415	1892
1893	9,640	586,260											595,900	2.9	20,035,082	1893
1894	15,000	433,827											448,827	2.4	19,931,158	1894
1895	50,000	382,526											432,526	2.1	20,505,917	1895
1896	55,000	581,832											636,832	2.8	22,474,256	1896
1897	50,000	630,408											680,408	2.3	28,485,023	1897
1898	25,000	788,720	20,523										834,243	2.1	38,412,431	1898
1899	15,000	774,000											789,000	1.6	49,234,005	1899
1900	5,000	778,625	24,271										807,896	1.2	64,420.877	1900
1901	15,000	850,687											865,687	1.3	65,797,911	1901
1902	10,000	690,601											700,601	1.1	63,231,836	1902
1903	1,000	1,117,541	5,675										1,124,216	1.8	61,740,513	1903
1904	500	1,404,524	74,852										1,479,876	2.4	60,082.771	1904
1905	2,500	1,993,915	33,000										2,029,415	2.9	69,078,999	1905
1906	800	2,614.762	50,700		180,217				56,200				2,902,679	3.6	79,286,679	1906
1907	675	3,836,286	36,676		353,672				41,225				4,268,534	4.7	86,865,202	1907
1908	1,037	4,127,311	63,363		240,384							690,410	5,122,505	6.0	85,557,101	1908
1909	525	4,838,109	61,722		442,486							704,605	6,047,447	6.6	91,831,441	1909
1910	1,850	7,065,736	75,168		753,232			774,473	69,268			256,483	8,996,210	8.6	106,823,623	1910
1911	207	3,979,264	110,165		1,052,751			1,241,535	100,407		158,344	20,000	6,662,673	6.6	103,220,994	1911
1912	1,509	8,113,525	289,906		1,356,184			1,775,898	166,520		81,391	288,656	12,073,589	8.6	135,048,296	1912
1913	...	10,418,941	1,079,466		893,408			1,947,933	115,355		156,984	441,959	15,054,046	10.0	145,634.812	1913
1914	992	9,350,392	1,214,670	2,200	462,199			1,212,342	58,321		60,272	322,846	12,684,234	9.8	128,863,075	1914
1915	4,026	8,283,079	1,022,814		115,696			415,009	14,445		890	53,388	9,909,347	7.2	137,109,171	1915
1916	1,695	11,386,577	1,113,296	9,610	225,140			477,832	20,033		257	63,103	13,297,543	7.8	171,201,534	1916
1917	....	14,153,685	1,299,976	63,302	309,991			567,969	35,516		7,482	89,614	16,527,535	8.6	189,646,821	1917
1918	558	20,537,287	1,358,638	100,004	381,074			528,672	44,141		569	159,044	23,109,987	10.9	211,301,897	1918
1919	500	18,294,495	1,365,127	97,841	571,949				41,276		3,189	713,205	21,087,582	11.9	176,686,390	1919
1920	.....	29,849,608	1,181,345	75,986	786,430				72,477		4,415	1,616,195	33,586,456	14.7	227,859,665	1920
1921	1,013	27,246,514	1,374,599	49,313	710,477				48,332		13,750	1,118,231	30,562,229	17.7	171,923,342	1921
1922		24,351,913	1,622,105	52,128	700,063			838,208	71,328	229,091	7,300		27,872,136	14.0	184,297,242	1922
1923		28,018;303	1,692,246	8,227	590,565			740,940	37,999	199,256			31,287,536	14.6	214,079,331	1923
1924		18,884,318	1,796,618	4,135	540,477		2,127	945,700	36,279	115,969	19,317		22,344,940	10.6	209,583,406	1924
1925		20,021,484	2,752,545	845,394	618,860	8,304	4,594	913,529	39,852	107,436	6,868		25,318,866	11.1	226,583,333	1925
1926	....	20,886,103	3,019,221	902,504	804,933	22,696	2,112	873,621	39,517	412,430	13,890		26,977,027	11.2	240,437,123	1926
1927	868	21,982,058	3,586,533	1,185,948	889,358	1,300	10,824	1,303,880	46,947	293,674	7,830	3	29,309,223	11.8	247,356,695	1927
1928	1,406	23,532,414	3,754,466	1,764,172	1,162,264		374	1,732,582	69,588	489,406	24,740	4	32,531,416	11.8	274,989,487	1928
1929	103	22,928,182	4,684,247	3,458,177	1,342,427		3,956	1,770,786	79,569	447,993	24,546		34,739,986	11.1	310,850,246	1929
1930	....	18,063,225	4,929,226	4,780,696	997,685		8,268	1,144,160	49,525	433,221	21,736		30,427,742	10.9	279,873,578	1930
1931	4,205	13,342.675	4,067,893	3,976,220	529,716		4,060	1,286,080	46,785	313,616	9,642	9	23,580,901	10.3	230,434,726	1931
1932	1,949	13,526,309	3,853,794	2,751,541	329,584		1,372	399,922	56,577	250,025	2,985	3	21,174,061	11.6	191,228,225	1932
1933	9,267	12,307,258	3,886,263	2,844,157	198,373		1,662	299,530	62,037	85,577	8,817	12	19,702,953	8.7	221,495,253	1933
1934	12,006	12,547,285	3.720,586	3,213,120	242,375		3,449	326,253	65,697	185,911	8,104	15	20,324,801	7.3	277,492,263	1934
	342,137	447,117,281	55,221,695	26,184,675	17,781,970	32,300	42,798	21,516,854	1,585,216	3,563,605	643,318	6,537,785	580,569,634	9.6	6,030,208,452	
% of Total Alberta Value	0.06%	77.0%	9.5%	4.5%	3.0%	0.005%	0.007%	3.7%	0.3%	0.6%	0.1%	1.1%				

TABLE II.

Mineral.	Value.	Percent. of Alberta's Total.
Coal	$447,117,281	77.0
Natural Gas	55,221,695	9.5
Cement	21,516,854	3.7
Petroleum	26,184,675	4.5
Clay Products	17,781,970	3.0
Sand and Gravel	3,563,605	0.6
Lime	1,585,216	0.3
Stone	643,318	0.1
Gold	342,137	0.06
Salt	32,300	0.005
Bituminous Sand	42,798	0.007
Other Products	6,537,785	1.1
Total	$580,569.634	

Table 3 shows these statistics in graphical form according to mineral products.

Table 4 shows, in graphical form, a comparison of the total value of minerals produced in Canada and in Alberta for the years 1886 to 1934.

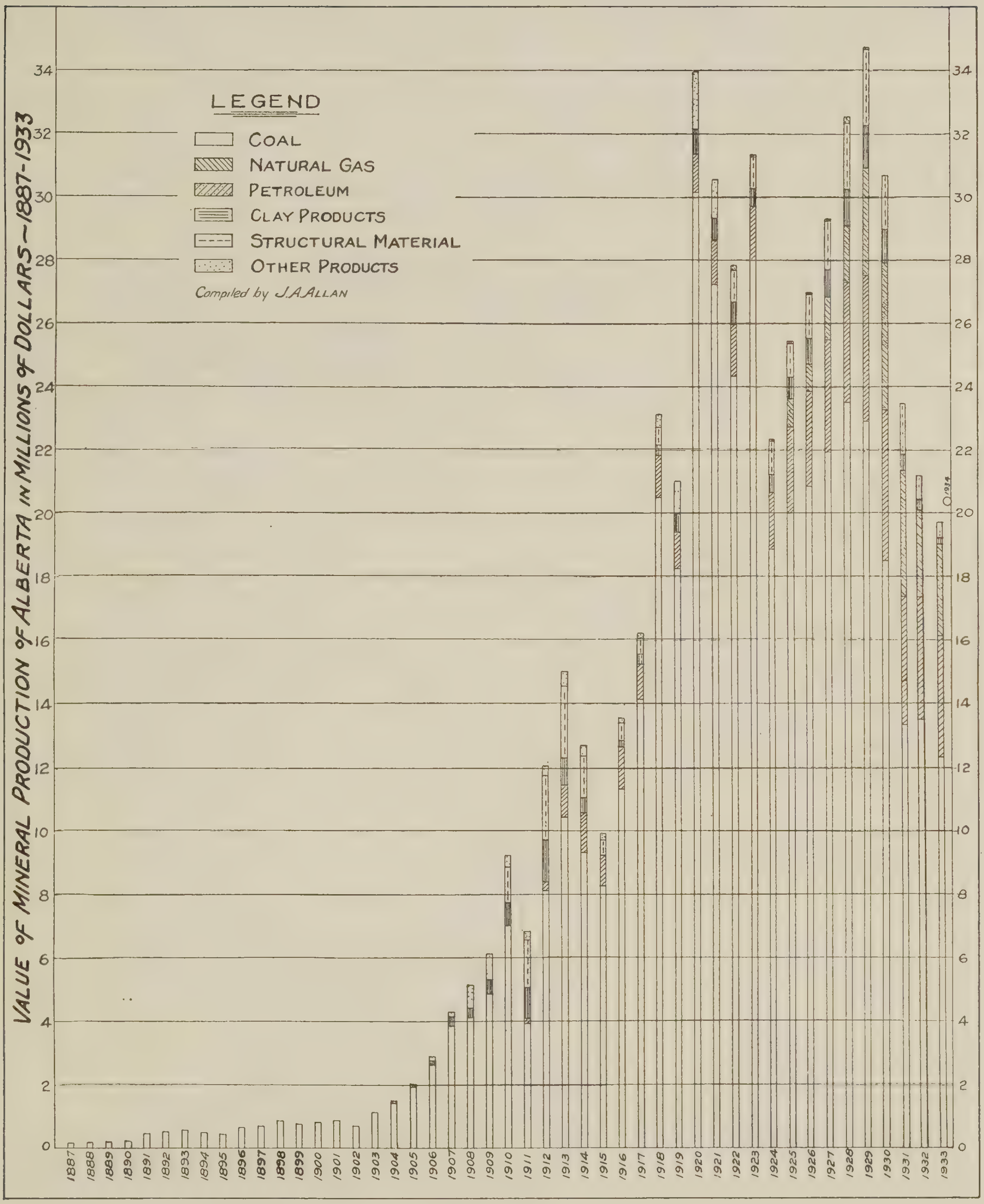
On the next four tables, namely 5, 6, 7 and 8, a complete story of the development of gold, coal, petroleum and clay products, in Alberta has been graphically represented, according to the recorded annual value of each of these mineral products. The annual production of the first two, gold and coal, from this part of Canada is recorded from 1887.

Table 5 is a graph showing gold production in ounces and value to date.

Table 6 is a coal production graph from 1887 to 1934.

Table 7 is a petroleum production graph from the beginning of the industry in 1914 to 1934.

Table 8 is a clay products production graph. The marked fluctuation in certain periods indicates clearly the changing conditions in the building trade within Alberta as most of the clay products are utilized within the province.


LEGEND
Coal
Natural Gas
Petroleum
Clay Products
Structural Material
Other Products
Compiled by J.A.Allan
Value of Mineral Production of Alberta in Millions of Dollars—1887-1933
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
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1900
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1902
1903
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1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934

TABLE III.

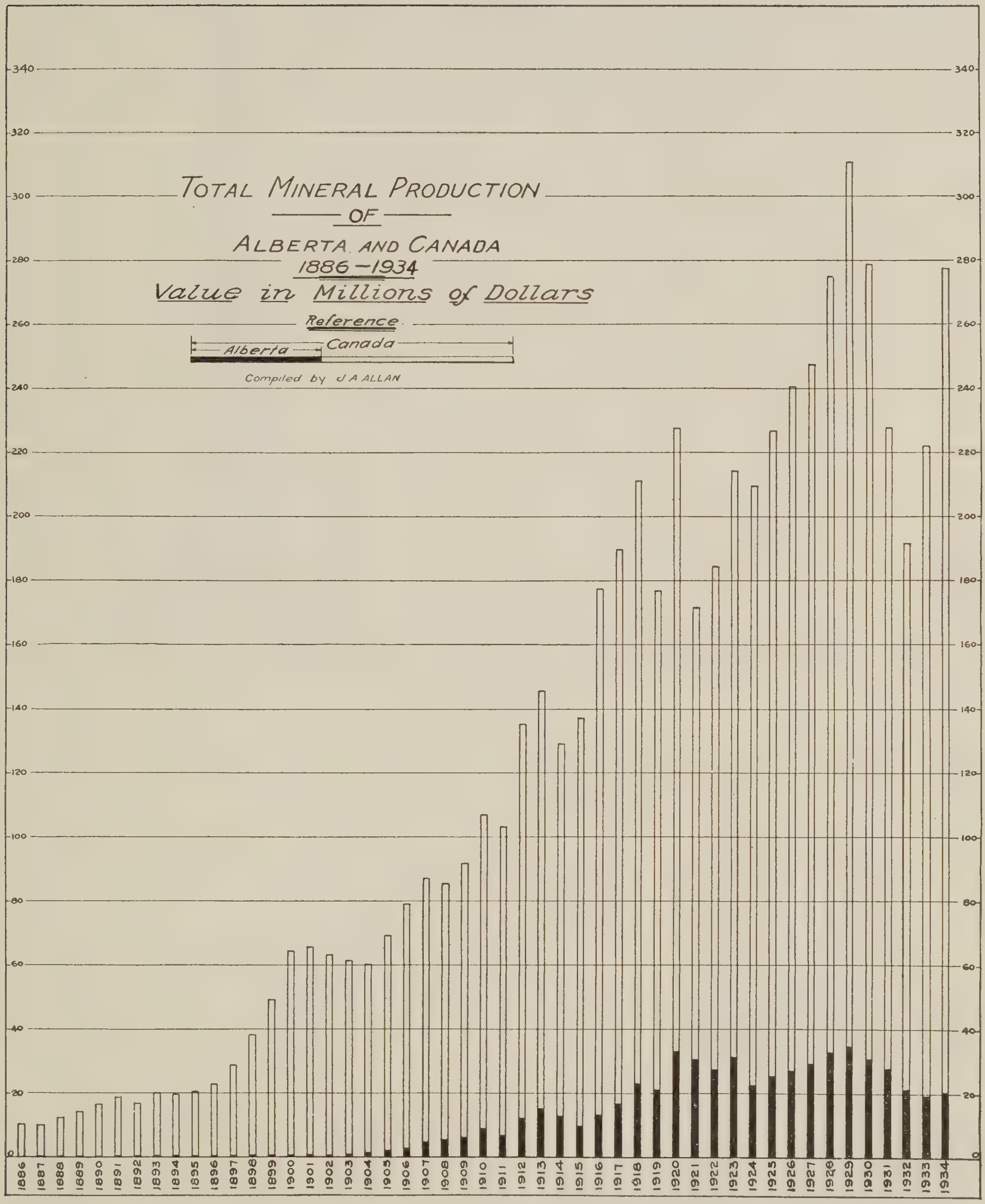

Total Mineral Production
of
Alberta and Canada
1886–1934
Value in Millions of Dollars
Reference
Alberta
Canada
Compiled by J A Allan
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934

TABLE IV.

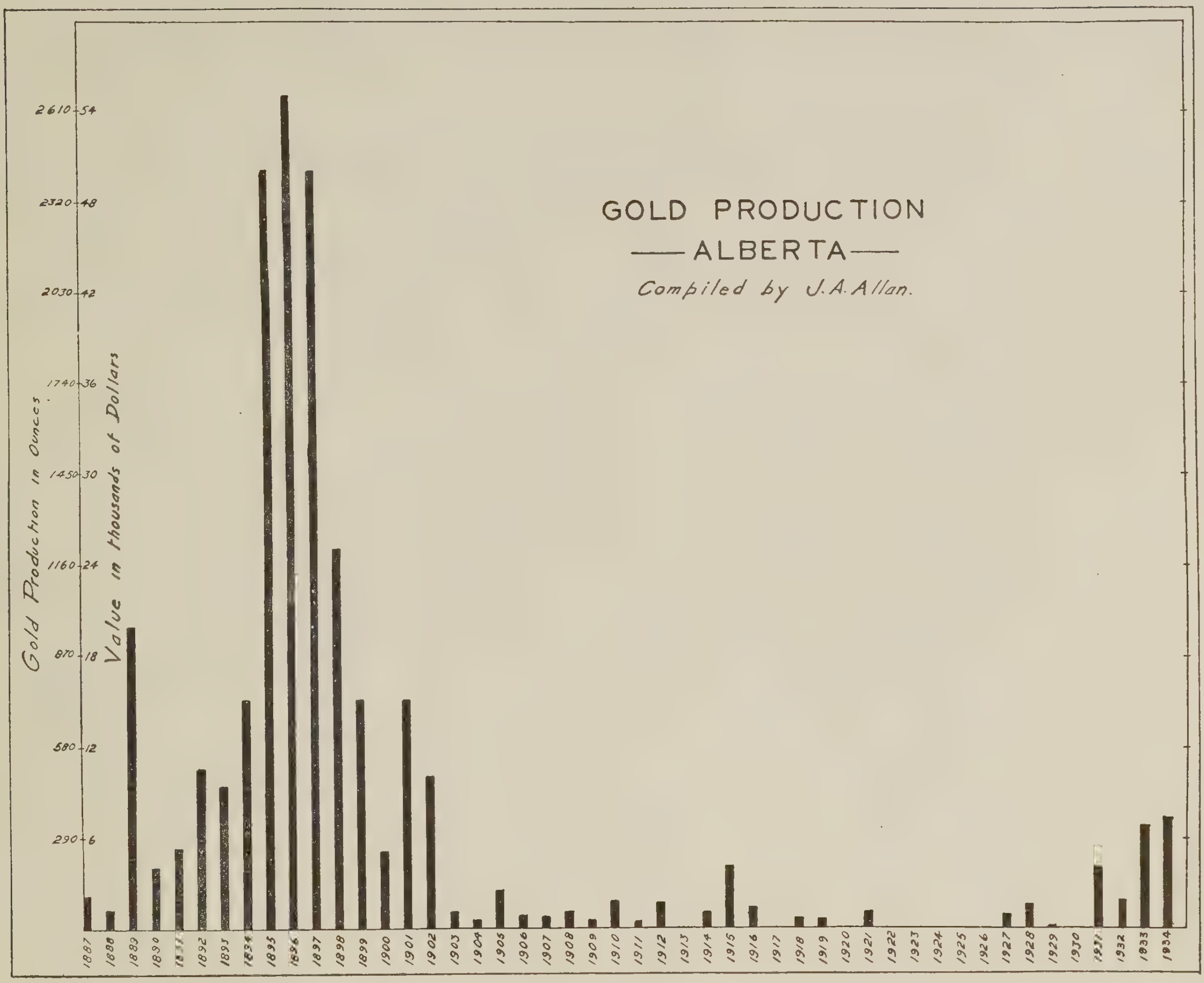


TABLE V.

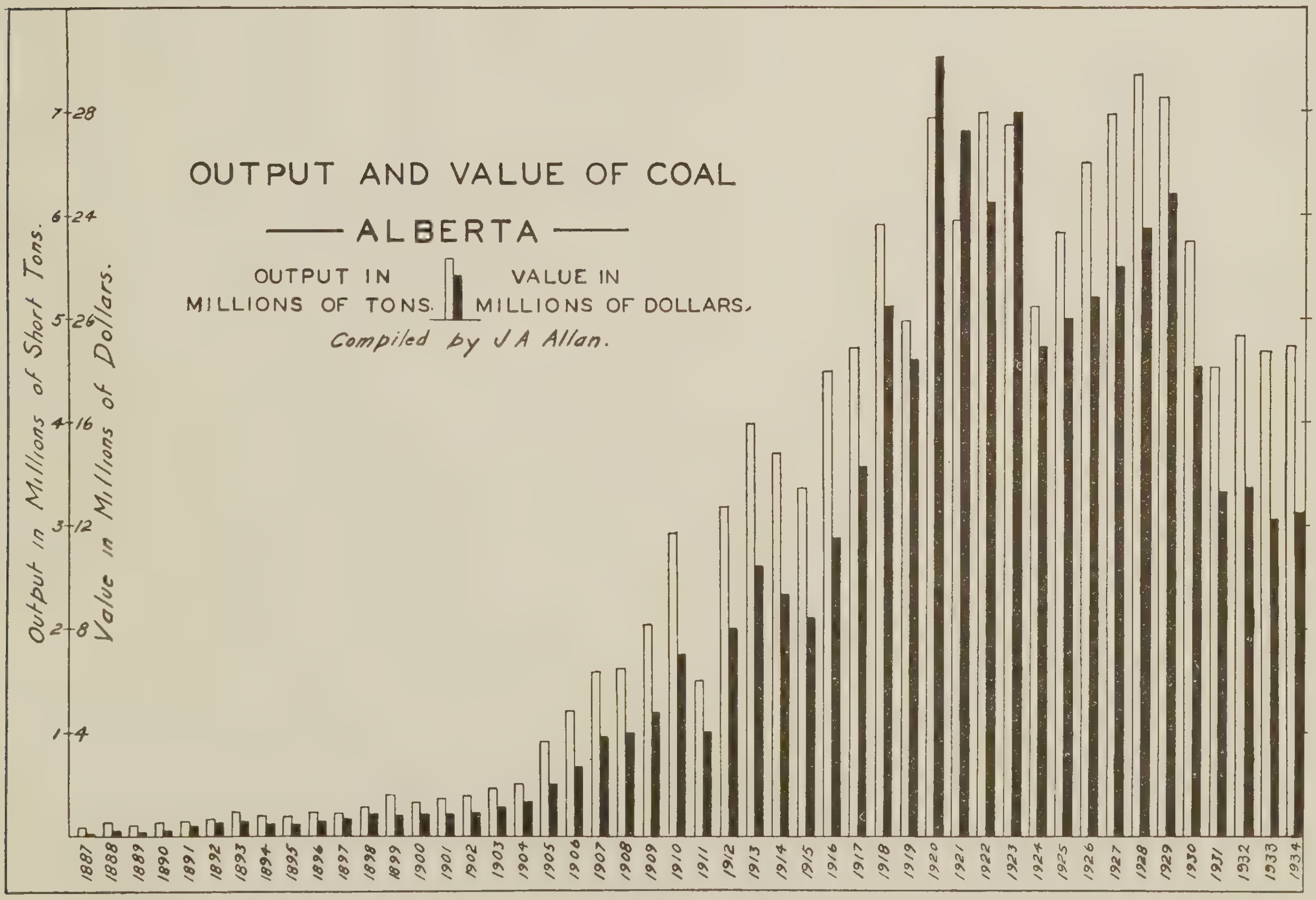


TABLE VI.

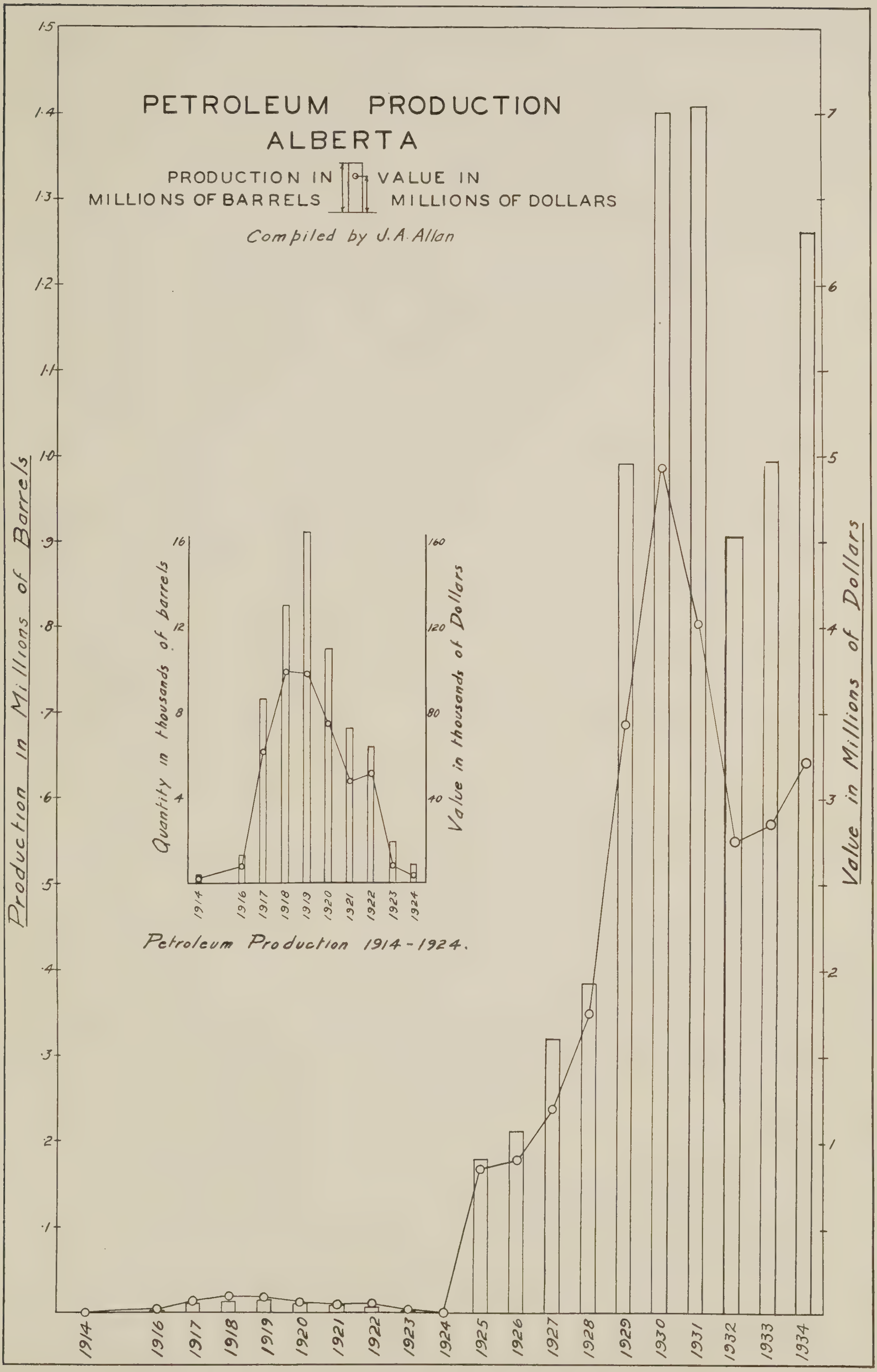

PETROLEUM PRODUCTION
ALBERTA
PRODUCTION IN MILLIONS OF BARRELS
VALUE IN MILLIONS OF DOLLARS
Compiled by J.A. Allan
Production in Millions of Barrels
Value in Millions of Dollars
Quantity in thousands of barrels
Value in thousands of Dollars
Petroleum Production 1914-1924.
1914
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934

TABLE VII.

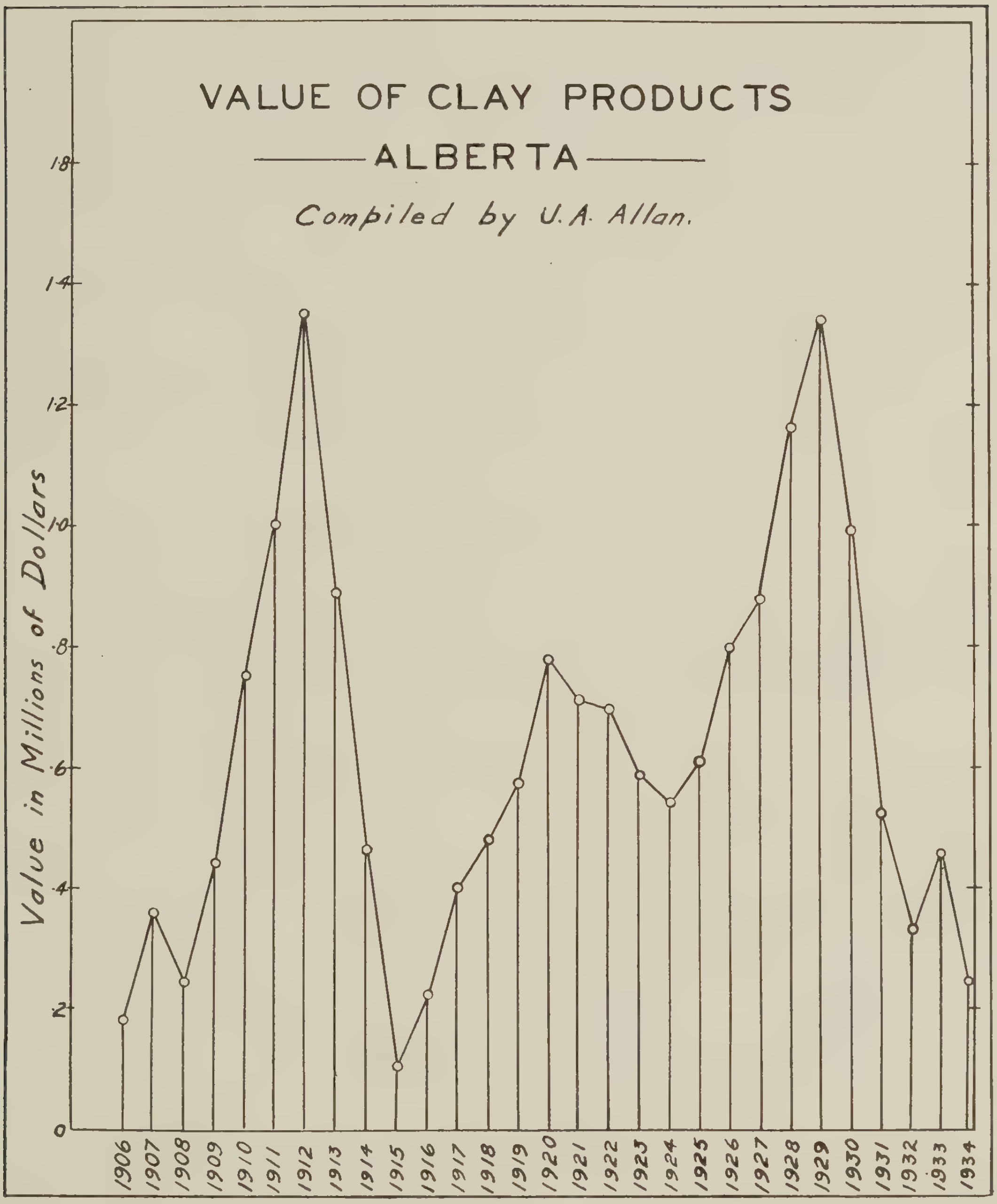

VALUE OF CLAY PRODUCTS
ALBERTA
Compiled by U.A. Allan.
Value in Millions of Dollars
1·8
1·4
1·2
1·0
·8
·6
·4
·2
0
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934

TABLE VIII.

Geological Examination in the District Between Smith and Cold Lake, Alberta.

(*R. L. Rutherford*)

During August and part of September, 1932, the writer carried out field work in the area extending from Smith eastward and south to Athabaska, Lac La Biche, and Cold Lake. Some information on parts of this district had been obtained on previous surveys. [See also Report 30 and map "Geology of Central Alberta, 1934.]

The chief object in this work was to obtain data relative to the distribution of the underlying formations and to the nature and distribution of the surface and recent deposits. In collecting geological data in these districts attention was also given to the relation of the source and supply of the domestic water.

Part of the general programme of the Geological Division has been the revision of the geological map of Alberta which was published in 1925 and is now almost out of print. Since this map was published considerable new data have been obtained in many parts of Alberta by our surveys and those of the federal government. Most of these recent surveys have been in the southern part of the province. In the revision of this map it was deemed essential that some work should be carried on between North Saskatchewan and Athabaska rivers in order to correlate the work done in the northern part of the province with that in the south. Furthermore, there has been less recent geological work done in this area than in most other settled parts of Alberta, and many of the numerous requests for information also pertain to this district.

Observations were made in the vicinity of the following towns, villages, hamlets or rural centres: Smith, Chisholm, Hondo, Athabaska, Meanook, Colinton, Boyle, Ellscot, Sorreil, Plamondon, Lac La Biche, Spedden, Ashmont, Bonnyville, Beaver Crossing, Cold Lake and numerous localities along the Beaver river from Lac La Biche eastwards.

The knowledge of the formations underlying these districts and geological conditions prevailing therein heretofore have been derived from earlier surveys made along the main drainage courses, namely the North Saskatchewan and Athabaska river valleys. These valleys give the most information relative to the character of the formation occurring at depth, but an examination of the intervening areas has been necessary, particularly to determine the character and distribution of the glacial and recent deposits which have an important bearing on the agricultural development of the districts. These recent deposits are also important as regards water supply and as a source of supply for highway surfacing.

Geological observations have been made along the Athabaska river by several workers. The most recent and detailed account of the geology along this stream in this area is that of McLearn[1]. The geological succession underlying part of this area is contained in his report, but no attempt was made to project the geological boundaries into areas adjacent to the river valley.

The geological succession as exposed along North Saskatchewan river has been reported on at different times. The latest and most detailed account of this section was prepared by Allan[2]. Allan's work was chiefly on the upper formation of the Upper Cretaceous succession and that of McLearn was largely on lower strata.

1McLearn, F. H. Geol. Surv. Can., Summ. Rept. 1916, p. 145.

2Allan, J. A. Geol. Surv. Can., Summ. Rept. 1917, Pt. C, p. 9.

The area examined by the writer lying largely between the Athabaska and the North Saskatchewan is in general underlain by the younger series as studied by Allan.

There is a marked absence of exposures of bedrock in the area between these rivers. Some of the tributary streams cut through the recent deposits and expose the underlying formations in their channels, but most of these exposures are in the lower part of these tributary valleys near their confluence with the main stream.

Allan divided the succession as exposed along the North Saskatchewan river into several formations or members. The later part of Upper Cretaceous time was here represented by fluctuating conditions of deposition resulting in an alternation of marine and fresh water deposits. The upper members of the Upper Cretaceous are collectively known as the Belly River series. The following are the formations named by Allan as occurring on the North Saskatchewan river:

Edmonton.
Bearpaw—not definitely determined.
Belly River series: Myrtle creek formation (freshwater).
Pakan formation (freshwater).
Victoria sandstone (freshwater).
Shandro shales (marine).
Brosseau formation (freshwater).
Lower Pierre: Lea Park formation (marine).

McLearn's work on the Athabaska river deals in large part with a succession that is lower stratigraphically than that occurring on the Saskatchewan river. Only one formation, namely the La Biche shale, occurs at the surface in the area considered in this report.

An attempt was made to try and interpret the distribution of the various divisions of the Saskatchewan river section in this area, but it was difficult to do much in this respect because of the scarcity of exposures of any appreciable size or continuity.

On the Athabaska river the marine series exposed at intervals from near the mouth of Pembina river beyond Athabaska and north for several miles is known as the *La Biche* formation. McLearn assigns a thickness of 1,100 feet to this formation. The upper part of it corresponds in general to the marine *Lea Park* formation of the Saskatchewan river section.

The most suitable geological horizon that may be used for mapping purposes is the top of the La Biche formation, or a corresponding horizon at the top of the Lea Park formation. This horizon is marked by a change from marine to fresh water conditions represented usually by a corresponding lithological change from shale to sandstone. The abruptness of this change is apparently marked in the general district between Athabaska and Boyle.

This formational boundary is well exposed on Muskeg creek about four miles south west of Athabaska (S.E. quarter of Section 1, township 65, range 23, west of the 4th meridian). Here the upper part of the La Biche shale formation is overlain by thick massive Belly River sandstone beds. The transition from shale to sandstone is represented by about fifty feet of sandy shales. In general the beds have a small dip to the south and west and the massive sandstones tend to express themselves in the physiography of the surface in places where the thickness of glacial material is not too great.

This formational boundary has been traced west from Athabaska to the east side of Baptiste lake, but west and north of here the glacial drift conceals the bedrock in all places examined.

It was hoped that some evidence of this geological boundary could be found on the Athabaska or its tributaries southwest of Smith. Traverses were made in the vicinity of Hondo and Chisholm, but no exposures of bedrock were found. Previous observations by the writer in the vicinity of Lesser Slave lake indicate that this geological boundary occurs approximately at lake level along the south side of Lesser Slave lake. This is at about the same elevation as the contact on Muskeg creek, and since there is no marked evidence of any appreciable structural change between these two places, the formations appear to have a strike slightly north of west and the basal Belly River beds should cross the Athabaska in the vicinity of Chisholm.

Previous geological maps have shown this geological horizon crossing the Athabaska a considerable distance above the mouth of Pembina river, which is south of Chisholm.

Exposures of Belly River beds on the Pembina near Flatbush indicate that this boundary has been placed too far south and from our recent work it is believed that the vicinity of Chisholm is more likely to be correct, although no exposures were observed here.

This formational contact is concealed in all areas examined between Chisholm and Baptiste lake, although the sandstone overlying the La Biche shales is believed to underly some of the higher hills in the intervening area. In general this contact occurs south of township 70 between Chisholm and Athabaska. It is also possible that basal Belly River beds occur capping some of the higher points on the north side of the Athabaska river and on the west side of Calling lake. This area was not examined but, if the general topography as shown on the sectional sheets is correct, there is a possibility of such beds occurring in the higher hills.

The valley of the Tawatinaw river is covered with glacial and recent deposits in the general vicinity of where this contact between the Belly River and La Biche shale would cross. Some river gradient data indicate, however, that this formational boundary crosses the Tawatinaw near the south end of township 64, north of Perryvale.

Basal Belly River beds are well exposed at several places between Colinton and Boyle. The massive sandstone of this series forms a north facing scarp ridge in part of this district. The best exposures are on Pine Creek in sections 10 and 12, township 65, range 21; on a small creek flowing north to Flat lake in section 35, township 64; section 2, township 65, range 20; and on a small creek flowing into Flat lake in section 8, township 65, range 19.

No exposures of bedrock were observed from the vicinity of Boyle east to Cold lake, due to the heavy cover of glacial and recent deposits. Allan has mapped the position of the basal Belly River on the Saskatchewan. This boundary was observed north of the river at one point, namely in the valley of Atimoswe creek, west of Elk Point.

A number of traverses were made across the district between Boyle and Cold lake, and whereas it is possible that some exposures may have been missed, especially on the upper part of the Amisk river, which was inaccessible to ordinary means of travel, it is felt that there is not likely to be much exposed in this district that would be of value in the mapping of the formations. The Beaver river was examined at a number of places between Lac La Biche and Beaver Crossing, but no exposures or indications of bedrock were observed along the valley of this stream.

Thus in the mapping the areal distribution of even the major lithological units a lot of interpolation is necessary in this part of the area. There is some evidence that basal Belly River beds occur near the surface at Amisk lake on the Northern Alberta Railway. From this point east the contact of the La Biche shales and the Belly river series is believed to follow a southeasterly direction for some distance until it swings south to cross the North Saskatchewan river.

Since exposures within this general area are so few that it is difficult to determine the positions of the major boundaries, it is obviously impossible with data available to map even the approximate distribution of the various members of these major divisions such as mapped by Allan on the North Saskatchewan river. Some discontinuous exposures occur at intervals along the valley of the Tawatinaw river in the vicinity of Rochester and Tawatinaw. These are Belly River beds, but it was not possible to determine their exact horizon. Similarly there are some coal bearing beds of the Belly River series occurring in the valley of Whitearth creek in township 61, and also similar beds in the valley of Flat creek near Ellscot.

The La Biche shales are exposed at several points along the Athabaska river and in the lower parts of tributary valleys, but with the exception of a small exposure on the south shore of Cold lake, no other outcrops of this formation were observed within the area. The writer is indebted to Mr. L. W. Shaw, Fisheries Inspector at Cold lake, for showing him this exposure on Cold lake, which is situated about a mile east of the village on the south shore of the lake. Mr. Shaw also took the writer to the north shore of Cold lake to examine an exposure of conglomerate that has attracted some interest in the past, as it was thought to possibly represent an outcrop of bedrock. This exposure is on the north shore of the lake a short distance east of the Alberta boundary. It was found to be a conglomerate of recent origin. Lake shore gravels have been cemented with calcareous material from a marl deposit.

Reference has already been made to the widespread occurrence of the surface mantle of glacial and recent deposits. In much of this area these deposits appear to be thick. The scattered and disconnected nature of the agricultural development in this area is in many respects due to the nature of these surface deposits.

In general it seems to hold that the thickness and coarseness of glacial deposits increase in a northerly direction in central Alberta. Such a change in character appears to be quite marked in the area between the North Saskatchewan and Athabaska rivers. The glacial deposits are in most places boulder clays, but in some places lake and river silts comprise the greater part of the deposit. The following summarizes in a general way the distribution of the most prevailing type of deposit in the respective districts.

Chisholm to Smith in the Athabaska valley:

Extensive deposits of river or lake silts. Very little coarse material. Occasional beds of gravel or pebbly sand.

Smith to Baptiste lake along and adjacent to the highway:

Boulder clays prevail. These extend south as pronounced ridges to the vicinity of Nestow.

Baptiste lake to Athabaska:

Recent deposits thin except in the lower part of the river valley where silts, sand and gravel terraces are common.

Tawatinaw valley from Nestow to Meanook:

Boulder clays, sands and gravels very abundant. Well sorted sands in the lower part of the valley at Rochester and Perryvale. Boulder clays prevail along the top of the valley.

Colinton to Boyle:

Recent deposits, thin in most districts.

Boyle to La Biche:

Pronounced ridges and hills of boulder clay, sand and gravel very abundant along the Northern Alberta Railway.

La Biche to Spedden:

Pronounced hills and ridges of boulder clays.

Spedden and Ashmont east to Cold lake:

There are numerous areas where hills and ridges of boulder clays prevail, but within this general district there are several relatively flat open areas where glacial deposits are not so evident. Districts of this type are those around Bonnyville and St. Paul. In many of the more level districts it is evident that there has been post-glacial laking and the silting up of these lakes has covered the coarser glacial material with a layer of finer material.

At the present time sand and gravel are the only materials being produced from this area that may be classed as mineral products. Sand pits are operated at Perryvale and Rochester in the Tawatinaw valley. Most of this material is shipped to Edmonton for use in the building trades. Gravel from pits near Elk Point have been used extensively for ballast on the Canadian National Railway grades east of Ashmont.

Coal seams occur at several places within the area and have been prospected at various times with a view to development, but in no case have the seams proven to be of sufficient thickness for commercial mining. Such occurrences have been prospected in the Tawatinaw valley at Rochester and further north towards Perryvale; on Pine creek in township 63; on Flat creek about two miles north of Ellscott; and on Whitearth creek in sections 35 and 36, township 61, range 19.

These seams all occur within the Belly River series, but are not at the same horizon. The occurrence near Ellscott appears to be the lowest in this series and that on Whitearth the highest stratigraphically. It is possible that some of these coal occurrences correspond in stratigraphical position to those mentioned by Allan in the Saskatchewan river section.

Drilling tests for oil were carried on in 1930 and 1931 near the Athabaska river to the east of Smith. Two wells, namely the Crudome and the Athadome, were started. The Crudome well was not drilled to sufficient depth to determine the possibilities of the district. The Athadome well in the N.E. quarter of section 20, township 72, range 24, was drilled to a depth of about 1,800 feet, where a quantity of gas and salt water were struck. This well was started at an horizon about 200 to 300 feet below the top of the La Biche shale formation. These wells are the most recent tests that have been made in the general area covered by this report. There were no previous tests at these points, but several wells were drilled along the Athabaska river at various points from the town of Athabaska down to McMurray a number of years ago. So far as the writer has been able to ascertain from field observation, there is no geological evidence indicating that the site of these recent tests is more favorable for oil possibilities than almost any other part of the whole area. The exposures are too few and widely separated to permit the working out of any local structure. Such could only be done in this area by means of test drilling.

The writer examined an occurrence of bituminous sand near Hondo. This outcrop has been taken by some to represent an oil seepage. This occurrence is of glacial origin similar to others, such as that at Mosside and at Nakamun, Alberta. The material has been transported from the well known deposits of bituminous sand on the Athabaska river at McMurray.

Some of the earlier test drilling on the Athabaska river has proven the occurrence of large quantities of gas in districts to the north of this area, and gas fields with production are known to the south and east, as at Viking and Kinsella. Consequently there is reason to think that there are gas fields within the area lying between the Saskatchewan and Athabaska rivers. At present this area has not been tested, and as there is no immediate demand for this commodity in excess of the present supply, it is not likely that tests will be made in the near future in this area unless the tests are for oil. Local structures can only be worked out by test drilling, as the exposures of bedrock are too few to determine other than the general distribution of the formations. This information, however, may serve as a guide to the possible drilling depths to certain horizons within different parts of the area.

Information relative to the water supply of the area was obtained at many places. In general, water is obtained from shallow wells in the recent deposits, or from streams. Occasional deeper wells have been bored or drilled into the bedrock, but there are few of such within this area. In general the water from the shallow wells is hard. This is a general feature of waters in Alberta that are obtained from glacial and recent deposits.

ROAD MATERIALS DIVISION

By K. A. Clark

The last annual report gave a general account of laboratory studies which revealed the important effect of the presence of acidity and of soluble salts in bituminous sand on separation by washing with hot water. It was found that by neutralizing the natural acidity of the bituminous sand by treatment with alkali practically complete recovery of bitumen became a simple matter. Study of the effect of various salts likely to be present in bituminous sand showed that trouble from this source could be avoided by use of soda ash as the alkali for neutralizing acidity. A more detailed, scientific report of these studies was published in a chemical journal of world wide circulation*.

Simplification of Separation Plant.

More understanding of how and why the separation process works has been sought in further studies. The work has been handicapped by the loss of all assistants at the close of the last fiscal year. However, considerable progress has been made.

One result of recent studies has been a great simplification of the separation process and equipment. Formerly the procedure was to heat and treat the bituminous sand in a mixer and then introduce the treated material into a stream of hot water forming part of a circulating system consisting of a large tank of water, a pump delivering sand and hot water to sand settling cones and a return conduit carrying the overflow from the cones back to the large tank. The bitumen collected as a froth on the surface of the water in the large tank and was skimmed away: the tailings collected in the settling cones and ran to waste. It has now been demonstrated that the entire circulating system may be eliminated and the separation process completed in the mixing machine. The bituminous sand is heated and treated by mixing it in a steam-jacketed mixer with sufficient soda ash to make it slightly alkaline. A volume of hot water, approximately equal to that of the bituminous sand is then run into the mixer quickly. Mixing is not interrupted. The bitumen collects on the water. After removing the bitumen, the contents of the mixer, now consisting of wet tailings and a small excess of muddy water, may be dumped to waste directly. Yield of bitumen and freedom of bitumen from sand are equally good as with the former procedure.

The simplified procedure is an improvement from the standpoint of laboratory studies. It is easy to handle and eliminates unnecessary operations which might complicate interpretation of results. Whether the simplifications are significant for large scale work is not obvious. They mean batch instead of continuous operation.

Nature of the Bitumen Froth.

The recovery of bitumen by the hot water separation process is dependent on the circumstances that when the bituminous sand is washed with hot water, the bitumen turns into a froth which floats on water buoyantly. The bitumen itself is heavier than water and sinks. It has always been something of a mystery how this froth forms and what factors affect it. The mystery has been considerably cleared by recent work.

*"Hot water Separation of Bitumen from Alberta Bituminous Sands." K. A. Clark and D. S. Pasternack, Industrial & Engineering Chemistry, *24*, 1410, 1932.

When the soundness of the simplified separation procedure had been established, this process was used to investigate the general separation problem further. In this work artificial bituminous sands were prepared by remixing sand tailings from bituminous sand and separated bitumen. By this expedient it was possible to determine the effect of large and small bituminous contents on separation. It was noticed that when a bituminous sand containing a small amount of bitumen was separated, the bitumen froth contained large bubbles. As the bitumen content of the bituminous sands was increased, the froths obtained on separation became less and less frothy. In fact when a sand containing about 30% of bitumen was put through the process, no froth at all formed; the bitumen separated and formed a layer on top of the sand in the water. It was also observed that as richer and richer bituminous sand was separated giving rise to less and less frothy froths, the amount of sand retained by the separated bitumen decreased. Further, the frothiness of the froth could be suppressed by adding water to the bituminous sand during treatment. It was to the content of bitumen plus water in the bituminous sand at the time of washing with an excess of water that frothiness was related; if this combined content was less than thirty per cent. a froth formed and recovery of bitumen was practically complete; as the combined content decreased, the froth became more frothy.

The way the froth comes about can now be seen a little more clearly. In ordinary bituminous sand the bitumen present is not sufficient to completely fill the spaces between the sand grains. Air fills the surplus space. When excess water is poured onto the bituminous sand being stirred in the mixing machine, the water displaces both bitumen and air from the interstices of the sand, the bitumen entraps the air and froth is formed. It is obvious that the less completely the interstices of the sand are filled with bitumen and water the more air there will be present to be entrapped by the bitumen on separation. It is also obvious that if the interstices are completely filled by bitumen and water there can be no air present and consequently no possibility of froth formation

Further Work.

Further studies indicated by observations made during the progress of the work reported in this and the last annual report, while having a direct bearing on bituminous sand separation, are likely to have significance in a broader field. Bituminous sand separation is accomplished by manipulating the factors that determine the behaviour of mixtures of bitumen and sand in the presence of water. But the same factors can be manipulated to accomplish entirely different purposes. For instance, in building roads the attempt is made to so arrange things that the action of the water on a mixture of bitumen and sand (or similar material) will not separate or otherwise disintegrate it. The observation that calcium compounds in bituminous sand can prevent separation is suggestive of possibilities in improving the weather-resisting properties of bituminous road aggregates. There is also much to be learned about the influence of very fine materials on the separation of bituminous sand, and the behaviour, under service conditions, of mixtures of bitumen or oil and sand for road work.

NATURAL GAS RESEARCH

BY E. H. BOOMER.

A brief summary of the results during the past year is given below.

Researches have proceeded along the same general lines outlined in preceding reports but, in general, on a smaller scale for part of the year because of reduced financial support. Investigations on the pyrolysis of natural gas went forward in the Calgary laboratory under P. E. Gishler, who had an assistant until June 30th. Hydrogenation experiments were carried out by J. Edwards here. Water gas-alcohol researches were carried on until April by H. E. Morris and G. H. Argue. Research on solubilities in hydrocarbon systems was carried on by G. H. Argue from May to September. During the last three months of the year the water gas-alcohol project was reopened by J. W. Broughton during part time.

Financial grants were obtained from both the National Research Council of Canada and the Research Council of Alberta, the former body contributing somewhat more than half the cost.

HYDROGENATION.

Bitumen.

The principal experiments in this section were carried out in a continuous four litre autoclave, equipped with a high pressure gas circulating pump, tar pump, column still and condenser, and gas scrubber, assembled to permit removal of gasoline as formed. It was found possible to reduce McMurray bitumen to oil with less than 2% of coke formation during a 24-hour run. The temperature of operation is of great importance and should be between 425 and 435°C. The pressure may be varied within wide limits, 2,000 to 3,000 lbs. per sq. in. appearing suitable so long as a high concentration of hydrogen is maintained in the gas phase. This condition is obtained by circulating the gas through oil scrubbers at autoclave pressure to remove hydrocarbon gases formed from the bitumen. The rate of gas circulation must be carefully controlled as it governs the rate and yield of gasoline as well as its quality. The catalyst used has been invariably molybdic oxide, and it has been found highly satisfactory when supported on an inert neutral substance. Sulphur compounds in the bitumen offer no serious drawback to the process inasmuch as the sulphur goes almost completely to the gas phase as hydrogen sulphide and not into the oil. The gasoline produced is of good quality and stability after light refining, and has a fair anti-knock value. The following figures summarize the conversions in a run at 425°C during which 5,000 gr. of bitumen were used:

Product.	% by weight.
Oil	71.8
Coke	1.9
Gas	8.5
H_2S	4.0
Mineral Matter	4.1
Water	1.6
Loss	8.1

Of the oil product, 5.4% was unconverted bitumen left in the autoclave and 85% boiled below 240°C. It has been found by experiments on the part of

the oil boiling above 225°C that it may be destructively hydrogenated to give gasoline. Slight alterations in present autoclave set-up and operation will give a complete conversion to gasoline. On the other hand, a different set of operating conditions will produce a large yield of excellent lubricating oils. These lubricating oils are superior in most regards to the standard products now on the market in carbon residue, viscosity index and pour points. This work is proceeding with a view to determining the best operating conditions and most suitable catalyst for each desired product.

Coal.

The hydrogenation of coal has not been carried out in the continuous autoclave. However, pending the time when the work on bitumen will be concluded, some experiments in a 0.5 litre autoclave, using a continuous flow of hydrogen and removal of oil as formed, were carried out. These experiments were done with a view to determining the optimum conditions for use in the continuous autoclave. They show that continuous and complete hydrogenation is possible and will depend largely on the problem of the mineral matter content of the coal.

Cellulose, Wood and Wheat Screenings.

As a matter of scientific interest, the reduction of cellulose materials as cotton and wood sawdust to oils by hydrogenation in a tetralin medium were investigated. It was found, contrary to reports of work elsewhere, that these materials could be completely reduced to oil, water and gas, emphasizing the powers of tetralin as an hydrogenating medium. These results suggested an investigation of some possible merit on the wheat screenings that accumulate in large amounts at Fort William and Port Arthur. These screenings are largely weed seeds, chaff and wheat, and are somewhat similar to wood in chemical nature. Samples were obtained and hydrogenated under various conditions in a tetralin medium. The process does not appear to be promising. The production of oil amounted to about 50% of the weight of the seeds, water 25%, gas 10% and solid residue 15%. The water and gas production are unavoid able because of the composition of the seeds, and the water introduced difficulties in refining the oil. The solid residue is large, and it was not possible to reduce it below about 15%. This unexpectedly high residue suggests that the seeds are more stable in structure than other carbonaceous materials investigated in a tetralin medium.

WATER GAS—ALCOHOL.

Very little additional material can be added to the last report on this subject. The possibilities of synthesis of ethyl alcohol from water gas are slight. As a consequence a departure from the present methods appeared advisable, and investigations were planned to determine just what reactions occurred that prevented the formation of ethyl alcohol while the lower alcohol and higher alcohols could be obtained. Also it was thought advisable to reopen an old line of attack on the problem of obtaining alcohols from natural gas by direct oxidation rather than through the intermediary step of water gas. This last investigation, the direct oxidation of natural gas under pressure, is the only one going forward at the present time, and only slowly because of the assistant being available only at a few periods in the week. No results of interest can be reported yet on the preliminary work done.

SOLUBILITIES.

This section, initiated in the Spring of 1932, deals with the mutual solubilities of gaseous and liquid hydrocarbons under pressures from atmospheric up to the critical value when the two phases become one. It is a field of great theoretical

and practical value. Modern developments in the use of extreme pressure in the chemical and petroleum industries make such data necessary, and in addition the results are directly applicable in elucidating the physical conditions in producing horizons of gas and oil fields, such as the Turner Valley area.

The system chosen for preliminary work was necessarily simple, and was the methane-hexane system. The classical laws of solution were not found to apply above pressures around 500 lbs. per sq. in., and the critical pressure of 3,500 lbs. was much less than expected. The bearing of these results on the Turner Valley field will be summarized. It should be kept in mind that only rough conclusions can be drawn since the Turner Valley system is complex and contains all the hydrocarbons from methane to dodecane and higher. However, methane makes up the greater part of the gas and hexane is typical of the naphtha. It may be stated that, on the basis of reasonable comparison between the methane-hexane system and the analytical data available on the Turner Valley products, it does not seem probable that a liquid phase exists in the producing horizon. The area is largely a gas field, the gas carrying some hydrocarbon vapours. As regards best operating pressures, conclusions are not quite so definite. It would seem probable that under conditions as they exist, the best operating back pressure is the highest whether or not a liquid phase were present in the sands. In the absence of a liquid phase, reducing the pressure would result in condensation in the well casing and a possible loss of naphtha.

PYROLYSIS.

The work on pyrolysis of Turner Valley waste gas was brought to completion in the large furnace. Various technical difficulties in the use of quartz tubes on an industrial scale and in the heating and handling of large volumes of gas were solved. Sufficient has been learned to show that the process as a source of benzene and aromatic tar is possible from the technical point of view. A satisfactory furnace of high capacity consistent with reasonable cost can be designed.

The yields of oil and tar are of the same general magnitude as obtained in the small scale laboratory experiments. For a single pass of gas, at least 0.3 gallons of oil and 0.15 gallons of tar are recovered per 1,000 cu. ft. of gas. The oil is largely benzene and the tar about 35% naphthalene. It will be noticed that the tar yield is lower than previously found, due to a fault in the furnace header design permitting carbonization of tar.

As a commercial process, capable of financial success, very special conditions are necessary. The foremost condition will be a low cost for gas. With the off-gas valued at not more than one cent less than the cost of the waste gas per thousand feet, and of course marketable, the refined light oil would have to carry a cost of between 10 and 15 cents per gallon and the tar about 3 cents per gallon. This figure takes care of all customary charges on a generous basis, and is based on a plant using 25,000,000 feet per day with a construction cost between $100,000 and $150,000. Capital of $800,000 to $1,000,000 would be required. These figures are based on lower than laboratory yields of oil and less than the probable maximum throughput. It must be emphasized that an assured outlet for the light oil is essential, the most promising being as a blending agent for gasolines of low anti-knock value. Finally, the cost of gas should be mentioned again in that each cent per 1,000 feet cost represents over 3 cents in the cost of the light oil. The process is a border line one and not to be considered so long as a stabilizer gas process described below remains possible.

The second part of this section deals with the pyrolysis of stabilizer gas. Stabilizer gas contains more of the higher gaseous hydrocarbons than does

waste gas, their densities being in the ratio 2 or 3 to 1, and as a consequence is pyrolysed more easily and with greater yields. No reliable estimates of the quantity available can be made, but it may be said that in 1931 between 3,000,000 and 5,000,000 feet were wasted daily. However, the gas was not readily collected because of the methods in use in the Valley. In the near future an oil absorption plant for treating Turner Valley gases will be operating, and quantities of stabilizer gas will be available at one point. Not less than 1,000,000 feet will be produced, and offers a promising material for a pyrolysis process.

A large number of small scale experiments in half-inch quartz and metal tubes have been made, as well as a series of some 20 experiments in a four foot long, 1½ inch quartz tube. This work has been done with a view to maximum liquid yield, and the production of gaseous olefines was investigated in the laboratories of the National Research Council at Ottawa. The yields of oil and tar are much higher than with waste gas, and in addition, large percentages of olefines, principally ethylene, occur in the off-gas. In round figures a single pass can produce 1.6 to 2.0 gallons of light oil and 1 gallon of tar per 1,000 feet, and an off-gas 100% greater in volume containing 20 to 30% olefines. A second pass with the off-gas will give a further gallon of liquid products and an off-gas containing about 15% of olefines. The yield based on the original 1,000 feet of stabilizer gas may reach 2.5 to 3 gallons of oil and 1.5 to 2 gallons of tar. Further passes of the off-gas do not appear warranted because of the increasing volume and decreasing yield. It is possible that recovery of the olefines after one pass might be preferable, followed by pyrolysis of the remaining gas. The large quartz tube in a gas-fired furnace does not show yields as high as those quoted above found with small quartz tubes. This may be due to the few experiments carried out being insufficient to determine appropriate conditions, or may be unavoidable in the sense that the tube size has an influence on the yield.

While not as much data is available as desired, there is no doubt that the production of benzene as light oil from stabilizer gas offers a great deal more promise than does the previous process discussed. The yields are so much greater, the temperatures can be lower for equal gas flows and the costs of recovery will be much less. Apart from the cost of the gas, the stabilizer gas process will have about a seven-fold advantage in costs over the waste gas process with possibilities of an even greater advantage should the olefines be utilized. Stabilizer gas is inherently more valuable than the waste gas, and while it is not put to use at present, it is highly probable that a considerable price would be set on it if a use were developed. However, a process using stabilizer gas could take care of a cost commensurate with the inherent value of the gas to Western Canada.

The Calgary laboratory was closed down on January 18th, 1933. Further work must necessarily be carried on in the Turner Valley if proper progress is to be made. The interest and support of the oil companies concerned would be advisable in co-operation with the Research Councils that have financed the work to date.

Acknowledgment is made to the Principal and staff of the Provincial Institute of Technology and Art and for their unfailing co-operation and kindness at all times during this investigation. My thanks are also due to the Royalite Oil Co., Ltd., and to the co-operation of their officials in the Turner Valley particularly, for providing the necessary crude naptha for the preparation of stabiizer gas, and for many other services. In addition, my thanks are due to the Canadian Western Natural Gas, Light, Heat and Power Co., Ltd., for the loan and care of several gas meters and the installation of low and high pressure gas fittings in the laboratory.

Report No. 29.

FOURTEENTH ANNUAL REPORT

OF THE

RESEARCH COUNCIL OF ALBERTA

1933

University of Alberta
Edmonton Alberta

FOURTEENTH ANNUAL REPORT OF THE RESEARCH COUNCIL OF ALBERTA

The need for economy resulted in a serious interruption in the work of the Council in 1933, although a skeleton organization has been maintained which can be again expanded when this is advisable. No separate vote of funds for the Council was made by the Legislature in 1933, but arrangements were made by which the University of Alberta took over the senior members of the staff of the Council and provided for the continuation of a small portion of the work. All continuing members of the staff, however, assisted in the teaching work of the University.

It should be noted that the National Research Council has given valuable assistance with the work on Fuels in recognition of the value to the Dominion as a whole, of the study of Alberta coals now in progress. They paid the salary of K. C. Gilbart, Assistant Engineer, Fuels, and also financed the attendance of a representative of the Division at Coal Meetings in Ottawa and New York.

FUELS.

During the year a third detailed coal survey across the Province was commenced. This will extend from the Mountain Park Area on the west through Prairie Creek, Coalspur, Pembina, Edmonton, Tofield and Camrose areas.

Other work included further studies of an "accelerated weathering" test, the oxidation of coal in relation to accuracy of analysis, measurement of coal oxidizability, ignition temperature of coal, and fusibility of coal ash. A more detailed report follows as an appendix.

GEOLOGICAL SURVEY.

No field parties were maintained during the year, but examinations were made of seven rather scattered areas in central and southern Alberta.

The above work was planned to assist in the preparation of a geological map of central Alberta, Townships 42 to 85 inclusive. A description of the above examinations and maps will be found in an appendix to this report.

ROAD MATERIALS.

Investigations were continued on the hot water process for bituminous sand separation, and a commencement was made with the study of soil mechanics and soil testing with especial reference to subgrade problems on Alberta highways. A brief account follows in the appendix.

SOIL SURVEY.

Soil surveys were confined to one area in Townships 74 and 75, Ranges 20 to 24, west of the 5th Meridian. A brief appendix to this report also refers to the relocation of settlers from the drier parts of the Province and to the preparation of a soil survey map.

NATURAL GAS RESEARCH.

Experiments were conducted on the continuous hydrogenation of Alberta bitumen and of Alberta coal. Economic possibilities are seen in the former as soon as the price of bitumen becomes comparable with that of crude oil.

Other work included studies on the pyrolysis of natural gas, high pressure solubilities of natural gas in a paraffin hydrocarbon, the oxidation of natural gas, etc. The production of wood alcohol and formaldehyde are also seen as economic possibilities. Further information is given in the appendix.

PUBLICATIONS BY MEMBERS OF THE STAFF.

"Milestones in the mining industry in Canada," by J. A. Allan. Presidential address, Canadian Mining and Metallurgical Bulletin, No. 253, May, 1933, pp. 155-168.

"A preliminary study of the eastern ranges of the Rocky Mountains in Jasper Park, Alberta," by J. A. Allan, P. S. Warren and R. L. Rutherford. Trans. Royal Society of Canada, vol. 26, sec. IV, 1933, pp. 225-248.

"A new deposit of gymsum in the Rocky Mountains, Alberta," by J. A. Allan. Trans. Canadian Institute of Mining and Metallurgy, vol. 36, 1933, pp. 619-635.

ROBERT C. WALLACE, *Director of Research,*

University of Alberta, Edmonton.

March 19th, 1934.

FUELS DIVISION

By E. Stansfield, W. A. Lang and K. C. Gilbart.

The staff of the Division throughout the year consisted of the three members listed above, without laboratory assistant. W. A. Lang assisted also in the teaching work of the Chemistry Department of the University during the 1933-34 session.

A student, H. Stansfield, completed the development of a method for determining the ignition temperature of coal.

Samples Received.

Provincial Mine Inspectors submitted 21 ordinary channel samples from operating mines, 9 sets of samples for the survey work, and 4 samples for weathering tests. Operators submitted 5 samples for briquetting, washing, ash fusion and other tests. Other samples included 13 coal samples from the University power house, 10 samples of lignite char and 4 miscellaneous samples.

Sampling and Analysis.

The determination of retained moisture in coal at 60% and at 97% relative humidity was continued during the year, and was found so satisfactory that it is now regarded as standard procedure. Full moisture-humidity curves were made for 10 coals.

During a study of accuracy in analysis, described later, it was found that coal oxidised notably if partially dried for analysis in air at room temperature (the process called air-drying) and absorbed gas if dried in natural gas at room temperature. It was later found possible to dry to any desired humidity samples as large as 150 grams by exposure for 24 hours, over a suitable salt, in a highly evacuated, 8″ desiccator. This method obviates oxidation and absorption and was made standard procedure in December. The humidity employed will be varied according to the humidity of the laboratory at the season. The air-dry analysis is computed for report to the moisture retained at 60% humidity as determined in the standard small scale test.

Alberta Coal Survey.

A third detailed coal survey across the Province was planned to extend from the Mountain Park Area on the west through Prairie Creek, Coalspur, Pembina, Edmonton, Tofield and Camrose areas. At least 15 samples will be required to cover these areas. A start was made with the 1933-34 mining season and 9 samples have been supplied by Provincial Mine Inspectors. The major part of the work had been completed on six of these at the end of the year and a start made on the other three.

The programme of work on these samples is, of necessity, less exhaustive than in previous surveys. One large sample of lumps is tested for weathering and specific gravity. A large, channel sample of coal (4 containers) is tested for proximate and ultimate analysis, calorific value, moisture retaining capacity, oxidizability, and fusion of ash. Furthermore, six samples of varying ash percentages are prepared by flotation on suitable heavy solutions, and these completely analyzed. The data obtained is employed to prepare curves showing the

variation of analysis of the coal with the ash content, and thus indicate the analysis of the pure coal.

ACCELERATED WEATHERING TEST.

The test developed a few years ago to evaluate the resistance of coals to disintegration during storage has been used in these laboratories since 1928. It was found, however, that the results obtained were not consistent. The principal source of error was found to be the lack of control of humidity in the current of air employed to air-dry the lumps of coal tested.

Several methods of humidity control were considered and tried, and finally a new apparatus was devised, constructed and found satisfactory. This consisted of an air-tight metal box, with a liquid-sealed air-tight metal lid, in which air of regulated temperature and humidity is circulated over the coal to be dried by means of a small fan. The humidity is controlled at the desired humidity by means of a suitable salt. A number of coals were tested at several different humidities and the determined "slacking index" of the coal plotted against the humidity employed. Some 30 tests were made in the new apparatus on 11 different coals.

It was found that the slacking index obtained when the coal was dried in the air of 20% humidity might be double that found with 40% humidity, and a far wider range than 20-40% is encountered when the humidity factor is not controlled. It is hoped that a definite humidity may be adopted for general use in this determination, so that in future only one test per coal will be required.

A paper covering the above work is to be presented to the American Institute of Mining and Metallurgy in February, 1934.

THE OXIDATION OF COAL IN RELATION TO THE ANALYSIS OF COAL.

It is well known that coal is easily oxidized, but the extent to which this interferes with accuracy in analysis is less known, and no satisfactory data were available to support the claim that established methods should be revised to avoid oxidation.

The two analytical processes most involved are the preliminary partial drying of crushed coal at room temperatures (called air-drying) and the determination of moisture at 106°C. Oxidation can be most readily avoided in this laboratory by the use of reduced pressures or by the displacement of air by natural gas. Change of weight of the sample, and changes in the determined moisture content and calorific value are used as indications of oxidation.

The problem was studied by carrying out, in triplicate, the routine operations of air-drying and moisture determination, on the samples tested during a period of about 3 months. Samples were treated in air, in vacuo, and in natural gas, and the results compared.

It was found that air-drying involved notable oxidation and consequent loss of calorific value, but that the practice here followed of using natural gas was also unsatisfactory due to absorption of gas and consequent increased calorific value. A vacuum method was tried and appeared so satisfactory that it was made standard procedure for the laboratory. The determination of moisture at 106°C, with a current of natural gas through the oven, had previously been proven accurate, as it is only at lower temperatures that the coal absorbs natural gas in notable quantities. Additional evidence was collected to show the extent of the error involved in the use of air in the determination of moisture at

106°C. In one case a coal showed 8.34% moisture when dried in gas and 7.75% when dried in air—a difference of 0.6%.

A paper describing this work was prepared for presentation to the A.I.M. & M.E. in February, 1934.

Determinations of the Oxidizability of Coal.

Two methods have been employed in the past in this laboratory to evaluate the oxidizability of coal. One of these involved determination of calorific value of coal before and after six hours heating in air at 106°C. The other involved determination of ulmins soluble in caustic potash before and after the same oxidation treatment. Neither of these methods is satisfactory as neither determines the actual oxidation involved.

A new method was devised for direct metering of the oxygen absorbed by a sample of coal whilst being ground in a ball mill filled with air. The method appeared to be simple, to require no special apparatus, and to involve little work. From time to time, however, it was found necessary to modify the apparatus and to add new features to overcome the many difficulties encountered. Far more time was spent on this work than was anticipated, but at every stage it seemed foolish to abandon the task with success in sight. Finally with the experience gained, the apparatus was redesigned and reconstructed and a routine test developed which gives promise of being satisfactory.

A notice of this method is included in the paper on coal oxidation prepared for presentation to the A.I.M. & M.E. in February, 1934.

Ignition Temperature of Coal.

It is improbable that any test can be devised that will give a definite and absolute temperature as the ignition temperature of coal. The test hitherto employed in this laboratory is empirical and gives a temperature which might better be described as the temperature at which the oxidation of coal in a current of oxygen becomes notably rapid.

A new test was devised, after many trials and failures, in which the temperature is measured of the stream of heated air in which a coal will just catch fire. A blast of air passes over an electric resistance heater, over a thermocouple junction, and up through a trap door of gauze. A very small briquette of coal is placed on the gauze from time to time and the lowest temperature at which the briquette will catch fire within one minute is recorded. It is worth noting that as the coal is soon converted by the hot air into a less inflammable char or coke, it seldom catches fire at all at a temperature at which it does not fire within a minute.

The runs made to date have not been sufficient to prove the reliability of the test.

Fusion of Coal Ash.

The two new furnaces referred to in the 1931 report were operated during the year. The surface combustion furnace was found to need certain changes to ensure uniformity of temperature within the muffle and these changes reduced the temperature attainable, at the desired rate of heating, to about 2,500°F. The molybdenum wire resistance furnace had to be modified to reduce heat loss, but after this change was taken up to 2,800°F without difficulty. This is the highest temperature of practical value in ash fusion tests.

A change was made in method for ensuring a suitably mild reducing atmosphere in the muffle during the test. A methyl alcohol-water mixture

containing 51% of alcohol by volume is vapourised and passed through a refractory tube to the back of the muffle chamber. The alcohol and some of the steam are decomposed and produce a gas containing approximately 50% reducing gas (hydrogen and carbon monoxide) and 50% oxidizing gas (water vapour and carbon dioxide). This was found to be a very cheap and satisfactory method of controlling the atmosphere, and was used in all three furnaces employed.

Determinations of ash fusibility were made at intervals throughout the year.

GEOLOGICAL SURVEY DIVISION

By J. A. ALLAN.

No field parties were maintained during the year because appropriations were not made available for this purpose. R. L. Rutherford spent two months, with an assistant, examining various areas in central and southern Alberta. The chief object of these examinations in rather scattered areas was to obtain additional information on the geology in central Alberta to be used in the preparation of the geological map which includes the central third of the Province.

Examinations were made in the following areas:

(1) Along the valley of North Saskatchewan river west of Edmonton, in the vicinity of Tomahawk.
(2) Pembina river north of Fawcett.
(3) Little Smoky River district, southwest of High Prairie.
(4) Hardisty and Lougheed districts, where the geological contacts of the Bearpaw formation were examined and mapped.
(5) The Bonnyville and Cold Lake districts and the eastern side of the Province south to Lloydminster.
(6) A traverse along the foothills belt from Cochrane, via Sundre to Rocky Mountain House.
(7) Porcupine Hills, the eastern part of the Crowsnest Pass district and south to Waterton Lakes.

The valley of North Saskatchewan river was examined west of Edmonton chiefly because of the gold placer activities that are being carried on in this valley. The object was, in part, to study the source of the fine gold in the gravels along Saskatchewan river, and in this connection special attention was given to the rocks in the vicinity of the Edmonton and Paskapoo boundary.

In the middle of August, Rutherford examined the geology southwest of High Prairie in the Little Smoky district, where certain geological points were in doubt. A similar re-examination of specific outcrops was made along Pembina river. Additional data were obtained on the relationship of the *Bearpaw* formation with the *Edmonton* formation above and *Belly River* formation below, in the eastern part of Alberta, along Battle River south of Hardisty and in the vicinity of Lougheed.

The writer accompanied Rutherford on an inspection trip from Edmonton to Cold Lake by way of Smoky Lake, St. Paul and Bonnyville. From Cold Lake a trip was made southward in the vicinity of the eastern boundary of the Province to Frog Lake and south of North Saskatchewan river to Lloydminster. From Manville a trip was extended northward to Myrnam and west to Vegreville. On this trip additional geological data were obtained relative to the distribution of the geological formations and the character of the surface unconsolidated deposits chiefly of glacial origin. A second trip was made with Rutherford across the Porcupine Hills to the east face of the Livingstone range, and south to the vicinity of the east side of the Crowsnest Pass district. A geological examination was also made of a belt from Cochrane northwards by Sundre to Rocky Mountain House. A preliminary examination was made of the Section along the Red Deer valley west of Sundre as far as Hunter valley in township 31, range 10, west of the 5th Meridian, where a well is

now being drilled. The structure from this site to the east edge of the Forest Reserve was only considered in a general way.

GEOLOGICAL MAP.

In 1925 a geological map of the whole Province was published by the Research Council of Alberta. The scale of this map was 1″ to 25 miles. Since 1925, the writer and R. L. Rutherford have been revising that portion of the geological map which includes central Alberta between townships 42 and 85 inclusive. Much of the field work that has been carried out in this time has been related to this map area. The data obtained have been sufficiently complete to warrant the publication of this map. It will be called "Geological Map of Central Alberta," and will be map No. 15 published by the Research Council of Alberta. This map is now being printed on a scale of 1″ to 10 miles, and nine colors will be used to distinguish the different geological formations. A short report, which is now being written, will accompany this map.

Much new geological information with respect to the distribution of certain formations will be included on map No. 15. Previously no attempt has been made to correlate or to map the geological formations that occur south of the North Saskatchewan river with those that occur along the valley of the Peace River. The boundaries between some of the geological formations in this area are mapped with as great a degree of accuracy as the outcrops will warrant. Much of the information of this map will be of value in any future development of the mineral resources in central Alberta.

MISCELLANEOUS.

Many requests have been received from farmers in various parts of Alberta asking, and in some cases pleading, for information on a local water supply. In most cases no assistance could be offered as the necessary information has not yet been obtained, and funds have not been made available to continue our investigation of water supply which was started a number of years ago.

A large number of requests have been received from individuals interested in gold placer mining along the rivers in Alberta. There has not been any pamphlet or report published on this important topic, and stenographic facilities have not been made available so that the information requested could be prepared and supplied to those asking for it. With assistance and appropriations curtailed at present it is not possible for this Division to render the service that it has done in the past.

There has been the fullest co-operation throughout the year with Petroleum and Natural Gas Division of the Department of Lands and Mines, and the writer acknowledges with thanks, the information on the logs of oil and gas wells which has been so willingly supplied by Mr. William Calder, Director of this Division.

ROAD MATERIALS DIVISION

By K. A. CLARK.

Investigational work on the fundamentals of the hot water process of bituminous sand separation was continued during 1933 in spite of the handicap of negligible funds and no assistants. A hundred or more separation runs were made in the small laboratory plant and the results analysed. A better understanding of the effect of clay and similar fine mineral matter in the bituminous sand was being sought. Such knowledge is important in connection with bituminous sand separation. Also it was hoped that findings would lead to light on the behaviour of mixtures of asphaltic oils and gravel used in highway construction in which clay and similar materials play a leading part that is very little understood.

Force of circumstances during the year led to the commencement of a new line of work, namely, the application of recent developments in soils mechanics and soils testing to subgrade problems on Alberta highways. The first step of learning the technique of soils testing was made.

SOIL SURVEY

F. A. WYATT, *Professor of Soils.*

The soil survey work for 1933 was confined to one area only. It included all or part of the following townships:

Township 75, Range 22, West of the 5th Meridian.
Township 74, Range 22, West of the 5th Meridian.
Township 75, Range 23, West of the 5th Meridian.
Township 74, Range 23, West of the 5th Meridian.
Township 75, Range 24, West of the 5th Meridian.
That part of Township 74, Ranges 20 and 21, south of the Little Smoky river.

Mr. J. L. Doughty made survey by sections of the above area for the purpose of locating settlers who were being moved from the drier parts of the Province. This area was set aside for the sole purpose of settlement of these families.

The better soil area extends across the south half of Township 75, Ranges 22, 23 and 24, and the north half of Township 74, Range 22, and the north-eastern part of Township 74, Range 23. This area contains about forty thousand acres, of which approximately 190 quarter sections were vacant at the time of the survey. It is estimated that approximately 100 of the vacant quarters have from ten to forty acres of either open or easily cleared land. The remainder is thickly wooded and would be rather expensive to bring under cultivation.

The above survey was carried out by the Department of Lands and Mines.

Later in the summer Mr. Doughty conducted representative parties of the prospective settlers into this area on two different occasions, and assisted them in selecting locations. This part of the work was conducted by the Department of Agriculture.

SOIL SURVEY MAP.

A soil survey map has been draughted by Mr. M. Polet, bringing together the results of surveys from adjacent areas conducted from 1928 to 1931. This map contains either all or part of the surveys from five different areas. The area covered by the map consists of Townships 69 to 86, Ranges 11, west of the 5th Meridian to 2 west of the 6th Meridian inclusive, or it might be described as the area adjacent to and between Peace River, High Prairie and Sturgeon Lake. This map on tracing paper now forms a permanent record of the soil surveys for the above areas, and is in a condition for publication when funds will permit.

Mr. A. D. Paul assisted in bringing together information from the various reports, and in transferring the soil areas from the various maps to the composite map.

NATURAL GAS RESEARCH

By E. H. Boomer.

The following brief summary covers the work carried out during the year 1933. The amount of work done was much less than in previous years because of the absence of financial support after the end of March. The National Research Council of Canada contributed the expenses of the work along one line during the summer months; but no work was undertaken after October 1st, due to lack of assistants and of time on the part of the writer.

Hydrogenation.

Experiments on the hydrogenation of Alberta bitumen in a continuous process were carried out satisfactorily. It was shown that gasoline and lubricating oils of high quality could be produced readily and that no technical difficulties existed. The best operating conditions were under investigation when this project had to be discontinued. The success of such a process for the utilization of natural gas, as a source of the hydrogen required for the production of gasoline and oils from Alberta bitumen, will depend primarily on the cost of crude bitumen. This bitumen, it should be noted, must be nearly free from mineral matter. The higher yield of oils from this process as compared to that obtained by cracking suggests that the latter process cannot compete. However, until the price of bitumen becomes comparable with that of crude oil, which at present is very low, no economic development can be expected.

A few experiments of preliminary nature were carried out on the continuous hydrogenation of Alberta coal for the production of oil. These experiments were discontinued before any definite conclusions could be given, but it would seem that the process will be applicable to Alberta coals. In this connection the career of a British plant to operate on a commercial scale with British coal will be watched with interest.

Pyrolysis of Natural Gas.

These investigations on the production of light oils, benzene and tar from Turner Valley waste gases were brought to a conclusion. Satisfactory results were obtained in operations on a semi-commercial scale as reported previously, and estimates were drawn up. It is believed that a profitable enterprise would result from an application of this process to the production of benzene for use as a superior blending agent for Turner Valley naphtha.

Further development work on a larger scale in the gas field and the solution of one or two technical problems will be necessary.

High Pressure Solubilities.

A preliminary investigation on the solubility of natural gas in liquid hexane was completed, and no further work has been done. Scientific results of great interest and no little importance were obtained. The primary objective, information as to the actual conditions in the producing horizon of a gas field, was not reached before the work had to be dropped. Because of this no conclusions as to the best operating conditions, or probable performance of a well, can be drawn at present.

OXIDATION OF NATURAL GAS.

This project, dealing with the direct oxidation of natural gas hydrocarbons to yield alcohols, aldehydes and acids shows distinct promise in its early stages. Viking natural gas has been used for convenience, and the influence of temperature, pressure and catalyst investigated. The investigation has suggested a process that shows every possibility of making a commercial success. Wood alcohol and formaldehyde are the primary products, and these have wide markets in Western Canada and command a relatively high price. The demand would increase greatly if a substantial reduction in price occurred, which does not seem improbable should further investigation bear out the promise in these preliminary experiments.

OTHER INVESTIGATIONS.

Other investigations along various related lines were discontinued in 1932. These included reactions in "water gas" produced from natural gas and experiments on hydrogenation with tar or tetralin for the reduction of cellulosic materials, such as wood and grain screenings, to produce oils.

Report No. 32.

FIFTEENTH ANNUAL REPORT

OF THE

RESEARCH COUNCIL OF ALBERTA

1934

University of Alberta
Edmonton Alberta

FIFTEENTH ANNUAL REPORT OF THE RESEARCH COUNCIL OF ALBERTA

In 1934, as in 1933, no separate vote of funds for the Council was made by the Legislature, but the University of Alberta provided for the continuation of a small portion of the work.

It is gratifying to note that the National Research Council has continued to recognize the value of the researches in progress to the Dominion as a whole, and has given financial assistance to the work on Fuels and to the work on Natural Gas. That Council paid the salary of K. C. Gilbart, Assistant Engineer, Fuels, and C. A. Johnson, research assistant in the Natural Gas investigations; it also assisted to finance the attendance of a representative of the Fuels Division at Coal meetings in Ottawa and New York.

Brief summaries of the work of the Fuels, Geological Survey, Road Materials and Natural Gas Divisions are given below; more detailed accounts are attached as an appendix to this report.

FUELS DIVISION.

The detailed coal survey across North-Central Alberta was continued during the year, but not completed. Good progress was made with studies relating to coal classification. The new method developed for measuring the oxidizability of coal was improved during the year, and a number of coals were tested. It is hoped to correlate the results with the tendency of the coal to undergo spontaneous combustion. A chemical study was made of the grey or curly coal found in parts of the Province. Four small samples of coal were examined microscopically by Dr. R. Thiessen, of the Bureau of Mines, Pittsburgh, a brief account of his findings being given in the Appendix.

The laboratory space allotted to the Division was curtailed during the year, and it was necessary to place in storage the equipment for house heating tests.

GEOLOGY DIVISION.

The work of the Geological Division of the Research Council is directed by J. A. Allan in conjunction with the Department of Geology, University of Alberta. R. L. Rutherford assists in teaching in the Department, and in return P. S. Warren determines all palaeontological material received by the Research Council.

No field parties were maintained during the season because funds were not made available. J. A. Allan and R. L. Rutherford made one visit of short duration into the foothills and Rutherford spent an additional two weeks examining localities of special interest. Much of the field season was spent by Allan and Rutherford in the office finishing a geological map of central Alberta and preparing the manuscript for Geological Report No. 30.

J. A. Allan conducted the office duties and supplied any available information to the numerous requests on the mineral and water resources in so far as data were available.

Notes on the progress of the Geological Survey Division in 1934 are given in a later part of this report.

ROAD MATERIALS DIVISION.

Further attention was given during the past year to the separation of bitumen from the bituminous sands. This work, along with former studies, has clarified understanding of the fundamental phenomena on which separation depends so that a simple, scientific explanation of the underlying principles of hot water separation of bituminous sand can now be given. A discussion of the process is presented in an attached report.

The work of the Council on bituminous sand separation is proving a useful guide to those attempting commercial work. Mr. Fitzsimmons, of the International Bitumen Co., made a number of visits to the separation plant on the Clearwater river while it was operating in 1930 to get suggestions for the design of his own plant. Mr. Max W. Ball, president of the Canadian Northern Oil Sands Products, Ltd., on his company's experimental experience, and in the light of the Council's published work, has modified his original separation scheme, involving the use of bentonite as a treating reagent and an ore flotation cell for frothing and floating the bitumen, to one corresponding very closely to what has been developed by the Council.

A modest field investigation of some of the "frost boils" occurring on our main highways was made during the past summer. Frost boils create part of the problem of securing stable road subgrades. The finding of the field work and subsequent laboratory examination of soil samples collected are presented in the attached report of the Road Materials Division.

NATURAL GAS RESEARCH.

The work of the year included a continuation of the studies of the solubility of gases at high pressure in liquid hydrocarbons, and a continuation of work on the oxidation of natural gas with the formation of methyl alcohol, etc. Work was also carried out on the corrosion of lead by sulphuric acid, at high pressures, in the presence of the organic sulphur compounds employed to odorize the natural gas distributed in Edmonton.

PUBLICATIONS BY MEMBERS OF THE STAFF.

Oxidation of Coal and the Relation to Its Analysis. E. Stansfield, W. A. Lang and K. C. Gilbart. Trans. A.I.M. & M.E., Vol. 108, pp. 243-254.

Effect of Oven Humidity on Accelerated Weathering Tests of Coal. E. Stansfield and K. C. Gilbart. Trans. A.I.M. & M.E., Vol. 108, pp. 237-242.

Optically Positive Cordierite from the Northwest Territories, Canada. R. L. Rutherford. Amer. Mineralogist, Vol. 18, No. 5, 1933, p. 216.

Geology of Central Alberta. J. A. Allan and R. L. Rutherford. Report No. 30, Research Council of Alberta, 1934, pp. 1-41+V. Accompanied by Geological Map No. 15 in 10 colors.

Decomposition of Ethyl Alcohol Over Some Poly-Component Catalysts. E. H. Boomer and H. E. Morris. Canadian Journ. of Research, 10:743-758, 1934.

ROBERT C. WALLACE, *Director of Research,*

University of Alberta, Edmonton.

February 23rd, 1935.

FUELS DIVISION

By E. STANSFIELD, W. A. LANG AND K. C. GILBART.

The staff of the Division throughout the year consisted of the three members listed above. W. A. Lang assisted in the teaching work of the Chemistry Department of the University. A student, H. Stansfield, assisted during the summer months.

The laboratory space allotted to this Division was notably curtailed during the year to provide additional accommodation for the largely increased classes in Mining Engineering. One office and one small laboratory were given up, and the house heating equipment installed in the large Mining Engineering laboratory was dismantled and placed in storage.

SAMPLES RECEIVED.

Provincial Mine Inspectors submitted 37 ordinary channel samples from operating mines, 5 sets of samples for detailed survey work, and 1 sample for weathering tests. Operators submitted 4 samples for special tests or analysis, and supplied 3 samples for special investigations. Other samples included 28 coal samples from the University power house, 1 sample from the Provincial Analyst for referee analysis and 6 samples from the Fuels Division of the Mines Branch at Ottawa for comparison analyses.

SAMPLING AND ANALYSIS.

No changes in regular methods of analysis were made during the year.

The vacuum desiccator method for "air drying" has proved thoroughly satisfactory, as has also the determination of "true" or "capacity" moisture. The moisture holding capacity was determined, for 46 samples of coal, at 60%, and at 97% relative humidity and from the latter the moisture holding capacity at 99.9% humidity(capacity moisture) was calculated. Full retained moisture-humidity curves were determined for 10 samples. The practice followed has been to report the capacity moisture when the total moisture differs from the former by more than 0.75%. The total moisture is more often above than below the capacity moisture, thus indicating that the sample received has surface moisture.

A study was made of rapid methods for the determination of sulphur in the calorimetric bomb washings. Two turbidity and several titration methods were tested, but none proved better than the well known benzidine titration. This sulphur value thus determined is used in calorimeter calculations.

A check comparison was made during the year of routine analyses as carried out in this laboratory and in the Fuels Testing Laboratories at Ottawa. This was particularly planned to check the determination of volatile matter in low volatile coals. Six samples from the Cascade Area of Alberta were supplied from Ottawa. The results as a whole were reasonably satisfactory, whilst the checks on volatile matter as determined in each laboratory in the electric furnace were remarkably close—an average difference of only 0.04%.

In certain coal mines bands of coal are found which differ in appearance from the adjacent coal. The coal in these bands is known locally as grey, granular or curly coal, and the consumer is prejudiced against such coals. A study was made to ascertain whether such prejudice was warranted by analysis. Five

samples of grey coal from the Wayne district were tested by proximate, ultimate and calorific analyses. The results were compared with two earlier analyses of similar coal and with analyses of regular coal from the same mines. In brief, it was found that analysis showed no noteworthy difference between the two types of coal. Any real difference must therefore be physical rather than chemical.

ALBERTA COAL SURVEY.

The third detailed coal survey across the Province, commenced in 1933, was continued in 1934. This survey across North-Central Alberta was based on 3 coal samples from the Mountain Park area, 1 from Prairie Creek, 3 from Coalspur, 2 from Pembina, 3 from Edmonton, 1 from Tofield and 1 from Camrose area. The work is not yet completed and is to be continued in 1935.

This investigation included proximate, ultimate and calorific analyses of the coal as mined; also fractionation studies for the preparation of charts showing the variations of these analyses with change of ash content. These charts, by extrapolation to zero ash, give the analyses of the pure coal as shown in Table I. Pure coal is commonly considered to be a mineral-matter-free, dry coal, but it is also sometimes considered as the mineral-matter-free coal but with the inherent moisture of the coal as mined; both analyses are shown in the table.

The investigation also included the following studies: A. The variation of specific gravity with ash content. Charts were prepared showing this relation, and from these were taken the value of the mean specific gravity for each coal, as mined, with 8% ash as shown in the table. B. Studies of the storage capacity of coal. These involved determination of the percentage loss of material through a ¼″ screen, due to disintegration, when the coal lumps are exposed to a cycle of air drying, immersion in water, air drying and screening as described on p. 72. This percentage loss is shown in the table as the slacking index. C. Studies of the oxidizability of the coals. This work is described in detail on p. 66. The results shown in the table are based on two sets of experiments: in the first the coal is continuously ground in air at 86°F in a ball mill for five or six days. The absorption of oxygen is noted by means of a gas meter during the test, and the apparent loss of calorific value due to oxidation is determined at the end. Some coals, particularly the bituminous coals, evolve gas (presumably methane) when first ground. This reduces the apparent absorption at the start of the test, so the comparison value has been taken as the absorption between the 24th hour and the 96th hour. In the second set of experiments four portions of coal of equal weight are taken, two of these are burned directly in the bomb calorimeter, the other two are similarly burned after first being exposed for 6 hours to a current of air at 225°F. This test gives the true percentage loss of calorific value due to oxidation. Summarized results of both sets of experiments are given in the table.

Studies of coal, as described above, are only reliable if the sample tested is freshly mined coal. It was impossible with a small staff to complete all the tests desired while the samples were still reasonably fresh. For this reason the table is incomplete and further work is planned.

It may be noted in Table I that the 14 coals reported are tabulated in order of descending calorific value of the pure coal with inherent moisture as mined. This is roughly the same order as the approximate distance of the mines from the eastern face of the Rocky Mountain range. The coals could also have been tabulated in order of descending fixed carbon, moist or dry; in order of ascending moisture content; in order of descending carbon; or in order of

TABLE I.

COAL SURVEY—TYPICAL NORTH-CENTRAL ALBERTA COALS

Coal	A	B	C	D	E	F	G	H	J	K	L	M	N	O
Geological horizon*	K	K	K	B	B	B	B	E	E	E	E	E	E	E
Approximate distance of mine east of mountain face—miles	0	0	0	13	13	14	22	98	141	110	155	150	161	156
Proximate analysis of pure coal, moist as mined:														
Fixed carbon %	74.6	67.4	63.4	55.0	54.3	53.3	51.0	49.8	44.0	46.4	43.0	43.8	41.9	41.1
Volatile Matter %	23.6	30.6	34.4	38.0	36.9	36.9	38.0	29.7	30.5	30.1	31.0	29.2	29.1	28.4
Moisture %	1.8	2.0	2.2	7.0	8.8	9.8	11.0	20.5	25.5	23.5	26.0	27.0	29.0	30.5
Proximate analysis of pure, dry coal:														
Fixed carbon %	76.0	68.8	64.8	59.1	59.5	59.1	57.3	62.6	59.1	60.7	58.1	60.0	59.0	59.2
Volatile Matter %	24.0	31.2	35.2	40.9	40.5	40.9	42.7	37.4	40.9	39.3	41.9	40.0	41.0	40.8
Ultimate analysis, pure, dry coal:														
Carbon %	89.80	88.35	87.00	82.70	79.80	79.80	78.90	76.40	76.30	....	74.95	75.85	....	....
Hydrogen %	4.90	5.45	5.45	5.60	5.10	5.20	5.25	4.55	5.00	....	4.95	5.10	....	....
Oxygen %	3.6	4.7	5.6	9.9	14.0	13.8	14.8	17.6	16.7	....	18.6	17.4	....	....
Nitrogen %	1.4	1.3	1.4	1.5	0.9	1.0	0.9	1.1	1.6	....	1.3	1.3	....	....
Sulphur %	0.30	0.20	0.55	0.30	0.20	0.20	0.15	0.35	0.40	....	0.20	0.35	....	....
Calorific value of pure coal:														
Moist, B.t.u./lb.	15,540	15,480	15,260	13,810	12,740	12,570	12,310	10,270	9,780	9,760	9,550	9,490	9,150	8,880
Dry, B.t.u./lb.	15,820	15,800	15,600	14,850	13,970	13,920	13,830	12,920	13,130	12,760	12,900	13,000	12,890	12,780
Fuel Ratio	3.2	2.2	1.95	1.35	1.35	1.45	1.35	1.70	1.45	1.50	1.30	1.40	1.40	1.40
Specific gravity of coal with 8% ash, moist as mined	1.35	1.33	1.32	1.33	1.37	1.39	1.37	1.37	1.34	....	1.34	1.33	....	1.32
Weathering loss, slacking index	0	0	0	0	1	1	1	32	31	41	40	40	47	39
Oxidizability in air†:														
Absorption of oxygen—at 86°F from 24th-96th hr., % of pure, dry coal	....	....	....	0.54	....	0.70	0.73	....	....	....	1.20	1.35	....	1.24
Loss of C.V. 120 hrs. at 86°F %	....	....	....	0.80‡	..	....	1.35	....	....	....	1.99	1.89	....	2.05‡
Loss of C.V. 6 hrs. at 225°F %	....	....	....	1.12	1.30	1.10	1.48	....	....	....	1.77	1.33	....	....
Softening temperature of ash, °F	2,640	2,370	2,480	2,145	2,160	2,120	2,100	2,280	2,050	2,370	2,440	2,010	2,055	2,380

Notes: *K:Kootenay; B:Belly River; and E:Edmonton horizons.
†See p. 66.
‡144 hours.

descending calorific value of the dry coal; each of these would have given a slightly different arrangement. It is evident that the order given is not necessarily that of the commercial evaluation of the coal, particularly since the comparisons shown are for coal freed from mineral impurity, and not for coal as sold.

CLASSIFICATION OF COAL.

There is at present no generally recognized classification of coal. The subject has received much attention during the past ten years, both in Canada and the United States. The Canadian and United States committees on coal classification found it necessary to devote several years to the study of old and new methods of analysis and tests, and the ways of computing comparative results therefrom. This laboratory has taken an active part in this work in co-operation with other laboratories; particular mention may be given to studies already reported of the effect of mineral impurities on the analysis of coal and the computation of pure coal analyses, the moisture holding property of coal and the differentiation between total and true moisture in wet samples, and the standardisation of the accelerated weathering test to avoid errors due to varying humidity during the test. Considerable time has been given also to the computation and plotting of Alberta coal analyses according to the many schemes of classification that have been advanced from time to time. Some of this work has been published.

Work carried out with relation to classification includes the three following: First the tabulation of all reliable coal analyses under the separate mines from which the samples were taken, and the calculation of the average pure, coal analysis. Previously such tabulations were made by townships rather than by mines, but the new figures will facilitate rapid interpretation of any classification in relation to the coal mines of the Province. Second, a study was commenced of the relation between the moisture and ash contents of any coal. The records of this laboratory indicate that the present accepted methods of computation commonly show too high a moisture content in the pure coal analysis; evidence is being collected to remedy this situation. Third, the coal values at present employed in coal classification are seriously affected by the mineral impurities in the coal samples as analysed, and the calculations necessary to bring these values to a comparable pure coal basis are far from reliable. Preliminary experimental studies of the distribution of the heat value of a coal between the volatile matter and the fixed carbon have shown that the relation between volatile heat and total heat gives a ratio which is little affected by mineral impurity in the sample, and that this ratio can be used in coal classification. This work is being continued.

DETERMINATIONS OF THE OXIDIZABILITY OF COAL.

Sixteen samples of coal were tested during the year to determine the resulting reduction of calorific value when they were heated for 6 hours, at 225°F, in a current of dry air. It might be noted that as the calorific values of both the fresh and the oxidized coal in this test are based on the weight of fresh coal taken, the results show the true loss of calorific value on oxidation. Coals normally gain in weight during oxidation, so that in similar experiments where the calorific value of the fresh coal is expressed as per unit weight of dry, fresh coal, and the final calorific value is expressed as per unit weight of dry, oxidized coal, there is a slight error due to this gain in weight and the calculated loss is called the apparent loss of calorific value. The 16 coals tested showed true losses of calorific value ranging from 0.5% with a bituminous coal to 3.0% with a domestic coal. Some of the values obtained are given in Table I.

A new method of determining oxidizability was mentioned in the 1933 report. In this method the coal is continuously ground, in a ball mill filled with air, for some six days, and the oxygen absorbed by the coal measured as it passes through a gas meter. The temperature of the apparatus is kept constant at 30°C (86°F). The oxygen absorbed from the air in the mill is replaced by fresh oxygen from a gas holder, any carbon dioxide evolved is absorbed by reagents, and the humidity in the apparatus is kept constant at 32% relative humidity by means of a suitable salt (magnesium chloride) and its saturated solution.

Fig. 1 shows the general plan of the apparatus. A is a gasometer containing oxygen, B and H are bottles containing a salt and its saturated solution to regulate humidity, C is a three-way cock to enable the apparatus to be brought to atmospheric pressure before reading the meter, D is a pressure gauge, E and F are safety seals to ensure that no air is drawn in or blown out through the seals of the mill box, G is a chamber maintained at 30°C by means of electric heaters, fan and thermoregulator. J is a Boys gas meter, K is an oil sealed connection, L is the oil sealed mill box, and M is the ball mill which rests on and is driven by two rollers.

The test is usually continued for 5 (or 6) days, and a curve plotted, but for comparison purposes it has been found best to employ the oxygen absorption between the 24th and the 96th hour of the test. The first 24 hours are omitted because it is not always possible to start the test with all conditions correctly established and because some coals, notably the bituminous coals, give off gas (methane) for several hours at the beginning of the test and so cause an apparent negative absorption. This latter condition is shown clearly in curves A and B of Fig. II.

Absorption values are reported as cubic centimeters of dry oxygen, measured at 30°C and 700 mm. pressure, per 100 grams of pure, dry coal, or as the percentage absorption by weight on the pure, dry coal basis. Figure II shows typical curves for 6 coals with a wide range of oxidizability; A was run No. 32 in Table 2, B run 21, C run 5, D run 10, E run 23, and F run 19. It will be noted that, in general, the higher the rank of the coal the less susceptible it is to oxidation.

The coal at the end of the test is re-analysed and the percentage reduction of calorific value determined. As it is not possible to determine the net gain in weight of the coal during the test, owing to oxidation, the reduction thus determined is the apparent loss as defined above.

In this work it is essential that the coal should be fresh when tested. Figure III shows the marked reduction in oxidizability of a coal after storage. The fresh coal was run 29 in Table 2, and the stored coal (73 days) was run 27 in the table.

It will be noted from the above curves that the rate of oxidation falls off notably for the first two or three days, but keeps surprisingly steady for the remainder of the test. This is more clearly shown in Figure IV, run 36, where the test was continued for 12 days. In another test in which coal, crushed to pass an 8 mesh screen, was stored in the mill without grinding for 37 days, the rate of absorption of oxygen showed little change after the first four days.

Table 2 gives a summary of results of coals tested to date. The days of storage of the coal before test are given in the table. It should be noted that in the storage test, run 27, the coal was stored with exposure to air, whilst in all the other tests reported the coal was stored in the unopened sealer as received

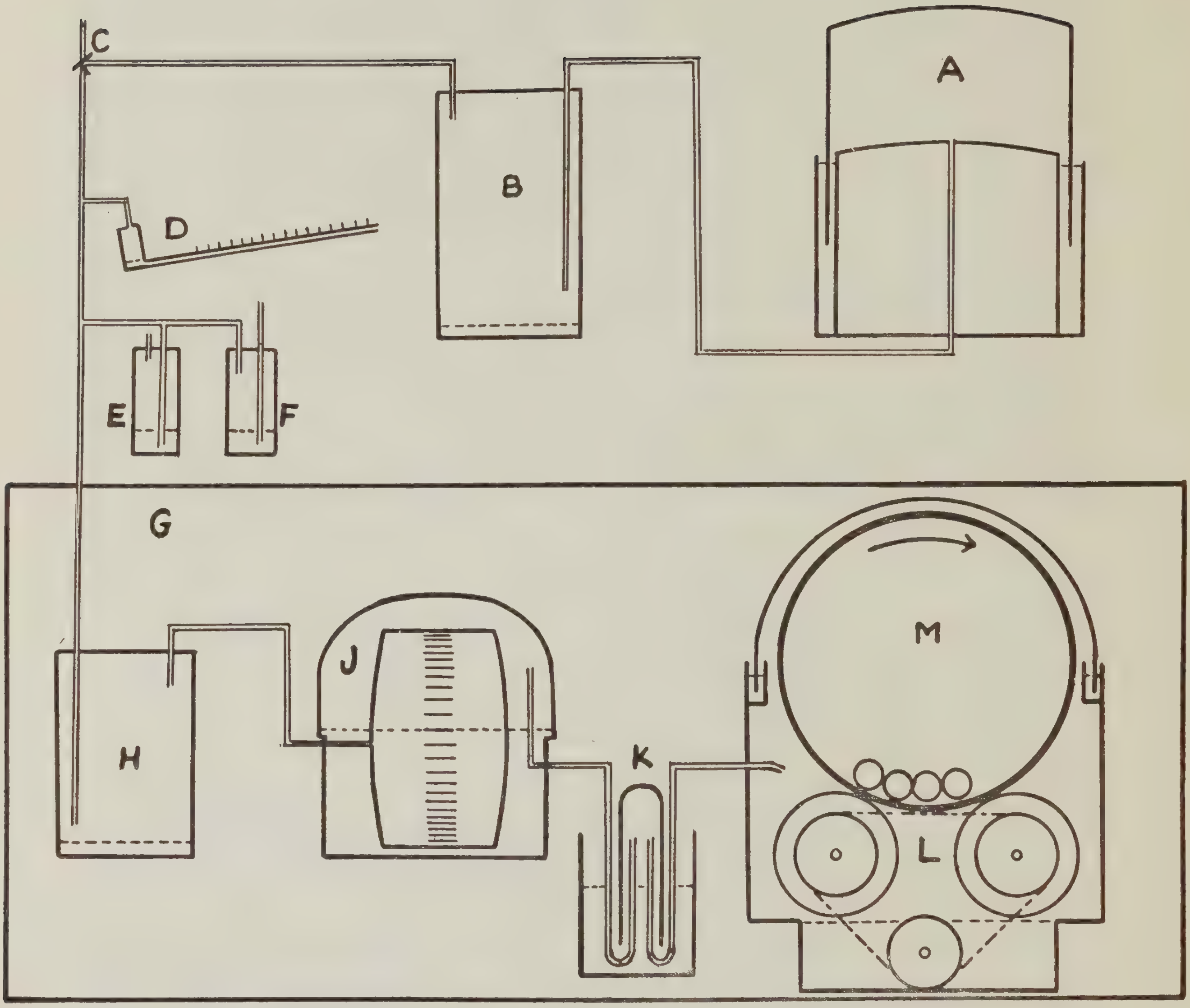


Fig. I.—Apparatus for the Determination of the Oxidizability of Coal.

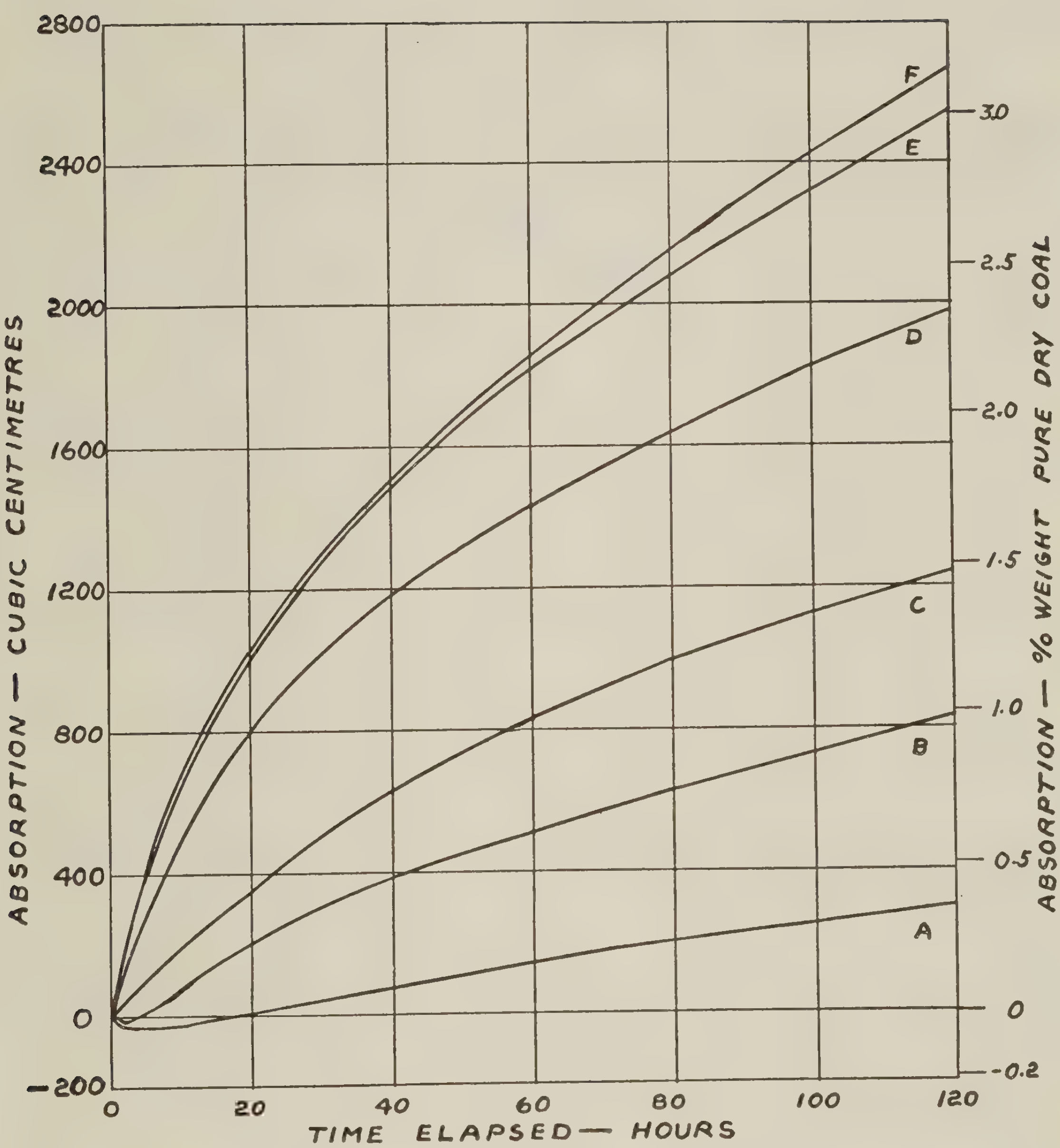
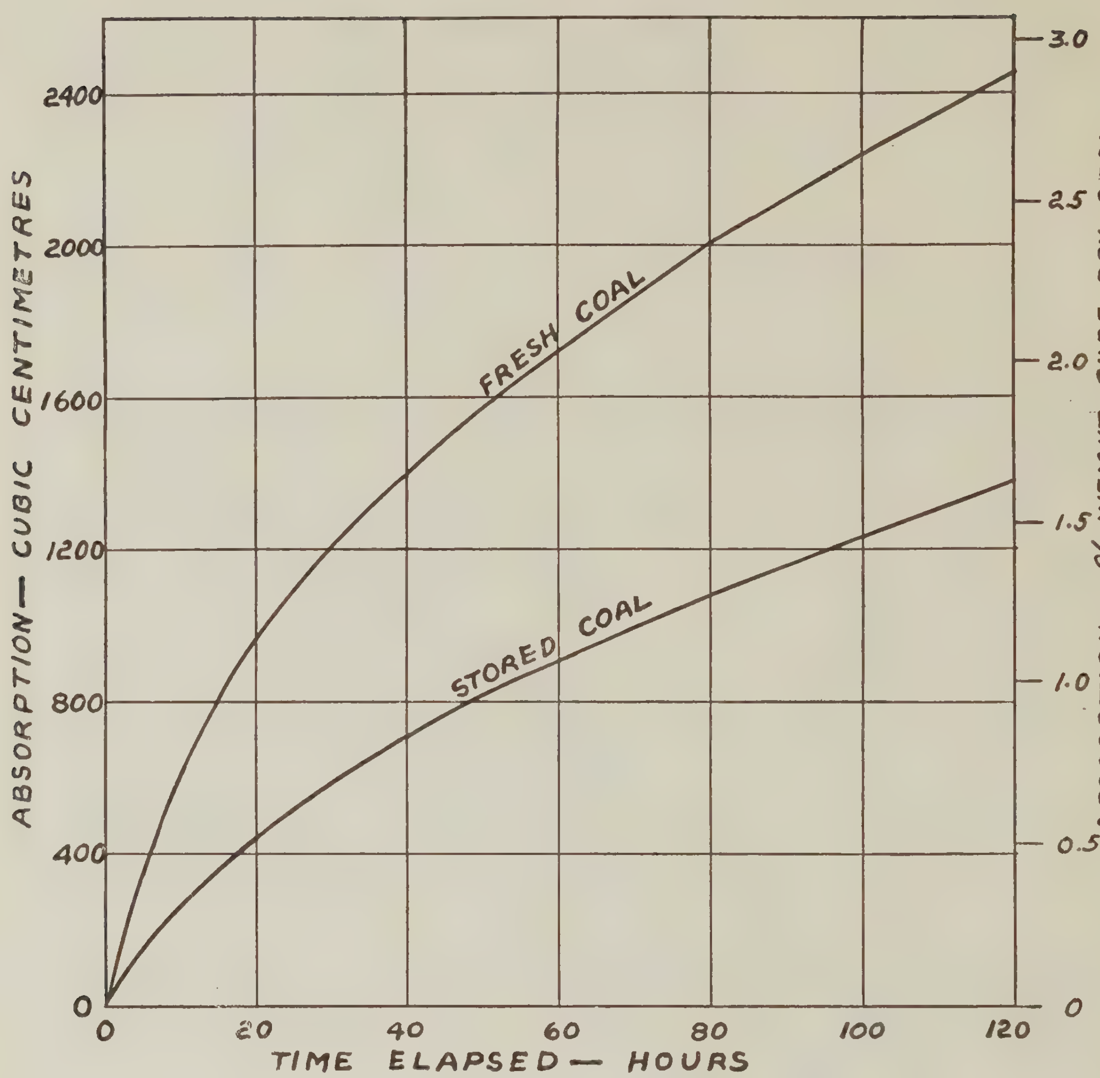


Fig. II.—Typical Oxidation Curves of Fine Coal.



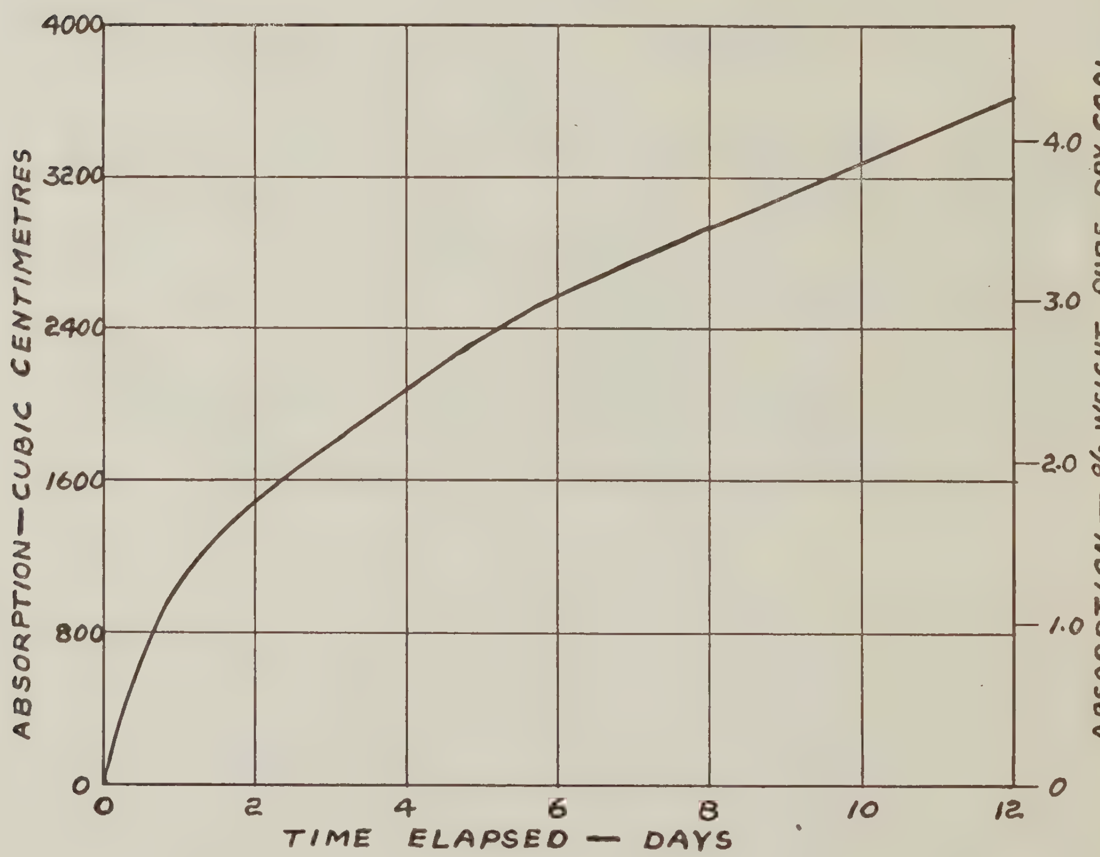


Fig. III.—Effect on Oxidation Curve of Previous Storage in Air.
Fig. IV.—Curve for Prolonged Oxidation.

from the mine in order to minimise oxidation. The higher rank coals will deteriorate less during storage than will the lower rank coals. A number of runs have been excluded from the table because of long storage.

Reference has been made to the gas evolved by some (bituminous) coals. Some preliminary attempts have been made to measure and analyse such gas.

It is hoped that ultimately it may be possible to correlate the results of these determinations of oxidizability with the liability of the coal to spontaneous combustion.

TABLE 2.

Run No.	Coal Rank*	Oxygen Absorbed† —Percentage weight of pure, dry coal		Duration of test Hours	Oxidation loss in Cal. Val.‡ %	Days stored before test	Gas evolved
		24th hour to 96th hour %	Total %				
32	76-153	0.27	0.36	120	0.46	4	yes
38	71-151	0.30	0.44	120	0.70	9	yes
33	69-151	0.31	......	120	0.92	11	yes
11	59-135	0.57	......	144	0.80	4	trace
21	58-134	0.54	0.97	119	......	8	trace
5	58-124	0.80	1.47	120	0.94	4	
26	60-122	0.70	1.32	119	......	21	
25	58-119	0.73	1.50	120	1.35	28	
8	57-118	0.89	2.03	168	2.02	11	
37	57-116	0.94	2.05	120	0.98	8	
22	61-116	0.85	1.81	120	......	10	
10	58-109	1.05	2.59	144	1.76	5	
36	59-106	1.21	4.26	287	3.20	3	
6	58-103	1.39	2.87	144	0.93	23	
30	59-102	1.33	2.89	120	2.02	5	
28	60-99	1.39	2.98	120	1.96	5	
13	59-95	1.38	3.13	168	2.03	8	
24	57-95	1.20	......	120	1.99	10	
14	58-94	1.38	3.26	144	2.13	1	
29	59-94	1.32	2.90	120	1.99	1	
27	59-94	0.83	1.63	120	0.93	73§	
23	58-93	1.35	3.02	120	1.89	3	
31	57-90	1.39	3.12	120	1.82	4	
19	56-88	1.46	3.48	144	2.76	5	

NOTES: *Coal rank—The coals are ranked by the percentage of fixed carbon in the pure, dry coal and by the calorific value of the pure coal, with moisture as mined. Thus 76-153 indicates 76% F.C. and 15,300 B.t.u. The higher rank coals are arranged in order of descending fixed carbon, the remainder in order of descending C.V.

†Oxygen absorbed is expressed as parts by weight per 100 parts of pure, dry coal; as absorption from the 24th hour to the 96th hour, and also as total absorption during the test.

‡The oxidation loss is the percentage loss in calorific value of dry coal, for the full period of the test. The calorific value of the oxidized coal is based on the weight of oxidized coal.

§This sample was crushed and stored for 73 days exposed to the air. The sample is from the same mine as the sample used in run No. 29.

ACCELERATED WEATHERING TEST.

The work reported last year showed that this test required standardization of the humidity of the air employed in air-drying the coal. It was settled, after consultation with the originators of the test, that this humidity should be standardized at the 32% relative humidity given by crystallized magnesium chloride in the presence of its saturated solution.

The procedure of the test is briefly as follows: A sample of freshly mined coal consisting of 18 to 25 pieces approximating $1\frac{1}{4}$ inch cubes, and weighing 500 to 600 grams, is taken for the test. The lumps are placed on trays inside the airtight metal box described last year, in which air at 30°C and 32% humidity is circulated over the coal by means of a small fan. At the completion of 24 hours of this air-drying, the sample is cooled to room temperature and immersed for one hour in water at the same temperature. The water is then drained off, the sample dried for 24 hours as before, and cooled. It is then subjected to a sieving, of carefully regulated degree, on an 8-inch circular sieve with 0.263-inch square openings, the undersize and oversize weighed, and the percentage of the undersize calculated; this is the gross loss. A duplicate sample of the original lumps is subjected to a "blank sieving" to match the above sieving and the percentage of undersize calculated. The gross loss, as determined above, is corrected by subtracting the percentage loss in the blank sieving, and the resulting number is termed the slacking index.

The American Society for Testing Materials suggests that coals with a slacking index below 5 are storage coals.

House Heating Tests.

The operation and efficiency of a "Francis Automatic Air Balance Control" furnace attachment were tested in a small bungalow in Edmonton. This attachment is essentially a thermostatically controlled, flue pipe check damper. A thermostat attached to the device opens and closes a butterfly damper across a side opening with change in temperature of the flue gases. The tests were still in progress at the end of the year.

Microstructure of Alberta Coals.

Four small lumps of coals were submitted to Dr. R. Thiessen, the well known authority on coal structure of the U.S. Bureau of Mines at Pittsburgh. One lump of coal was from a mine in the Saunders area, two from mines in the Coalspur area and one from Lethbridge. Dr. Thiessen very kindly examined these samples and submitted a report illustrated with 16 micro-photographs of thin sections. He emphasized the fact that the samples were too few and too small to represent the coal beds, and that it was dangerous to draw conclusions under these conditions. His findings of the actual samples were as follows: "The outstanding characteristics of these coals are: (1) finely to micro-bandedness; (2) highly attrital nature with advanced state of decomposition and maceration, and (3) high concentration of 'opaque' matter.

"The most outstanding characteristic from a petrographic standpoint is the high concentration of 'opaque' matter. The 'opaque' matter in these coals is similar to the 'opaque' matter in the 'splint coals' of the Paleozoic times, in which it forms the splint-making ingredient, but it is less dense than in the Paleozoic coals. The three samples from Saunders and Coalspur contain a high enough concentration of 'opaque' matter to characterize them as 'semi-splint' to 'splint' coals; the Lethbridge sample has a high enough concentration to characterize it as a semisplint coal, as compared with the Paleozoic coals."

Dr. Thiessen's conclusions are understood to indicate that the free burning, non-coking quality of these coals may be owing to the nature of the plant remains from which they were formed rather than to lack of geological age and metamorphosis. It is interesting to note that certain free burning, smokeless coals in the United States are sold at a premium as splint coals.

MISCELLANEOUS.

A study was made for the Attorney General's Department of the effect of heat on cans of evaporated milk and on the combustibility of such milk.

E. Stansfield attended meetings of the Canadian committee on coal classification at Ottawa, and of the United States committee at New York, during February. He presented two papers at the Annual Meeting of the American Institute of Mining and Metallurgical Engineers in New York at the same time.

E. Stansfield also presented a paper, "The Evaluation of Coal by New and Improved Methods," to the Western Annual Meeting of the Canadian Institute of Mining and Metallurgy in Calgary in September. He subsequently visited some of the coal mines in the Crowsnest Pass.

GEOLOGICAL SURVEY DIVISION

BY J. A. ALLAN.

This is the third year in which no field parties were employed because appropriations were not made available for this purpose. Accompanied by R. L. Rutherford a trip was made, in July, into the foothills south of Calgary, and observations were made on structures at the south end of Turner Valley which had been interpreted in part from drilling records.

Rutherford made a further examination of the strata and unconsolidated deposits in the Lake Wabamun district, and he also obtained further data on the occurrence of placer gold in the gravels along the North Saskatchewan river west of Edmonton. A trip of short duration was made into the Wainwright district to investigate the occurrence of specially marked boulders. The markings appear to be of early Indian origin, but a further study is being made of these boulders. Other field trips of short duration were planned, but road conditions brought about by frequent rainfalls prevented this field work from being accomplished.

The greater part of the field season of 1934 was spent in the office preparing the manuscript for Report No. 30.

GEOLOGY OF CENTRAL ALBERTA.

The first geological map of Alberta was compiled by the writer and published in 1925 by the Research Council of Alberta as Map No. 10. During the past ten years R. L. Rutherford and the writer have been revising the geological map of central Alberta and have prepared a new geological map which includes central Alberta between townships 42 and 85 inclusive. The map was finished and forwarded to the printer in March, and the proof of this map was edited in April by the authors. Between May and August a report was prepared on the geology of central Alberta to accompany this map. The report, which is numbered 30 in the series published by the Research Council of Alberta, was printed in September and was distributed with the map to a mailing list with 662 names.

The report is general rather than detailed in character and occupies 41 pages. The map which accompanies the report covers an area of approximately 100,000 square miles. A black and white relief map of the same area is included in the report. On this relief map is shown the area between each one thousand feet from 1,000 to 4,000 feet and also the area over 4,000 feet above sea level.

Much new geological information is contained in this report and shown on the map. Even the method of describing the formations and in discussing their distribution is somewhat different. Because the relief varies from plains topography on the east to high mountain topography on the west, and with foothills belt between, we have discussed separately the geology in the plains first and the geology in the foothills and mountains second. One of the principal contributions to the geological knowledge of Alberta is the correlation that has been accomplished on the formations exposed south of North Saskatchewan river with those occurring along the Peace and Athabaska rivers and southward.

With one exception the formational names used formerly have been retained. Only one new name has been added, that is the "*Foothills series*" for the succession of freshwater or brackish water strata younger than the Upper Cretaceous

marine beds in the foothills. It is not yet possible to subdivide this series into formations, but this series is known as strata equivalent to the *Belly River*, the *Edmonton,* and part of the *Paskapoo* formations in the plains in the east and in the southern part of Alberta.

The *Foothills series* is not exposed in any one section. Thicknesses for this series of 11,000 to 13,000 feet have been determined by measuring a series of gently dipping beds for a considerable horizontal distance. These measurements are probably greater than would be obtained from vertical sections because in places the beds are lenticular in character. It is possible that at some future date detailed geological work might permit of the separation of this thick series into more than one formation, but with the knowledge at present available it seemed advisable to use this general formational name *Foothills series.*

The section on economic geology in this report is brief and only the more outstanding facts are recorded. No endeavor was made to correlate the coal horizons across central Alberta because there are several reports on specific coal areas and reference has been made to these. The occurrence of petroleum and natural gas is very briefly considered, but references are given to publications issued by the Geological Survey of Canada on these mineral products. The occurrence and association of gold with the river gravels is referred to, but is not fully discussed because much field work has yet to be done on the study of the placer gold in Alberta. Attention is also drawn in this report to deposits of salt and gypsum, but the occurrence of these minerals has been described by the writer in various publications that are referred to in this report. The phosphatic character of certain rocks within the front range of the Rocky Mountains is a subject that has received the attention of the writer for several years. Cross-reference has been made to publications on this mineral product in Alberta.

At the present time the only mineral resources being developed within the area represented on this map are, coal, at various points from Clover Bar to Mountain Park; natural gas in the Viking district, and petroleum in the Wainwright district. A few years ago there was a small brick industry, but this industry has temporarily ceased. There are clay resources available for development when the demand is sufficient to maintain an industry.

One of the most important problems requiring investigation in this province is a detailed study of the underground water resources. Considerable data have been obtained, but very little information has been added during this year because of lack of funds to carry on field work. Numerous requests have been received from farmers, from communities, etc., for information on the water supplies. Unfortunately, in most cases no assistance could be rendered because the required information was not available. The writer is of the opinion that much valuable scientific data on the water resources in certain parts of Alberta can be obtained by carrying out field investigations, but this can only be done when finances are available and when field work can be undertaken.

MISCELLANEOUS.

The writer acknowledges the fullest co-operation that exists with the Petroleum and Natural Gas Division of the Department of Lands and Mines. Thanks are extended particularly to Mr. William Calder, Director of this Division, for this co-operation and for the information supplied to the Geological Survey Division on the logs of oil and gas wells drilled in 1934.

During the year the Geological Survey of Canada supplied a profile section model, in celluloid and colored geologically, to the Department of Geology at the University of Alberta. This model, prepared by Dr. B. R. MacKay, illustrates the geology and structure in the vicinity of Hillcrest, Alberta. This model has proved beneficial in work undertaken by the Geological Survey Division of the Research Council of Alberta, and the writer extends his thanks to the Director of the Geological Survey of Canada, for his co-operation with the provincial survey expressed in this manner.

Assistance was given in the drafting of the soil survey map of the Peace River, High Prairie and Sturgeon Lake Districts, prepared under the direction of F. A. Wyatt.

ROAD MATERIALS DIVISION

By K. A. Clark.

Bituminous Sand Separation.

Investigation of the hot water method of separating bituminous sand was continued during 1933-34 to the degree that no assistance and meagre appropriation permitted. Little new advance was made, but a better insight into the significance of what was already known was gained. The main phenomena upon which the process depends can now be pointed out clearly.

Acidity in Bituminous Sand.

The fact that water does not displace the bitumen from the silica grains of the bituminous sand under acid conditions is of primary importance. It has long been the practice to use alkaline solutions in bituminous sand separation, but the real function of the alkali was missed. This function was revealed when the Research Council investigated the unexpected difficulty it encountered with its separation plant on the Clearwater river in the north.[1] The trouble was shown to have arisen from the presence in the bituminous sand, from the adjacent quarry, of ferrous sulphate carried in by ground water. The salt hydrolysed forming sulphuric acid. The small amount of silicate of soda used for treatment of the sand failed to neutralize this acid and very poor yields of sandy bitumen resulted. Subsequently, in the laboratory, it was shown that when sufficient alkali was used to neutralize the acid, practically complete recovery of bitumen retaining a low content of mineral matter followed. Much of the bituminous sand has but little acidity and very little alkali suffices to establish a neutral or alkaline condition in the separation plant. However, it is unsafe to take this for granted, and provision should be made for testing the treated sand before it reaches the stage where the bitumen is displaced from the sand by water to be sure that neutral or alkaline conditions prevail.

Various alkaline reagents have been used for treating bituminous sand. Caustic soda, caustic potash or alkaline salts of sodium or potassium are generally effective. Lime will not do, however, since lime in very small amount prevents displacement of the bitumen from the sand. The same is true for magnesium hydroxide. Because of the harmful effect of calcium and magnesium hydroxides, trouble may arise from the use of caustic soda since this reagent would generate hydroxides from soluble calcium or magnesium salts present in the bituminous sand. Sodium carbonate is the most practical treating reagent. It is cheap, and any calcium and magnesium salts present, if converted into carbonates, have no bad effect on the separation process unless present in large amounts.

Clay is a troublesome constituent of bituminous sand when present in quantity. It causes the bitumen to form a suspension in the water and reduçes the yield. Where clay partings are encountered in the bituminous sand the percentage of clay in the material coming to the separation plant can become quite large. It is probable that the difficulty could be overcome by washing out the clay in a preliminary treatment in cold water.

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[1]Twelfth Annual Report, Research Council of Alberta, 1931. Industry and Engineering Chemistry *24*, 1410, 1932.

Froth Formation.

In hot water separation of bituminous sand the bitumen, after having been displaced from the sand grains, floats to the surface of the water. Yet the bitumen is heavier than water. It floats because it forms a buoyant froth. Consequently an understanding of this froth formation is important.

Considerable light on the froth formation has been gained through study of the separation process in a simple form. The whole process can be carried through with no more apparatus than a steam jacketed mixing machine. A charge of bituminous sand is placed in the machine along with some sodium carbonate solution and allowed to heat and mix. A test is made on the heated and treated bituminous sand to determine whether its acidity has been neutralized. If so, it is flooded by the addition of a volume of water about equal to that of the bituminous sand charge poured into the mixer. The paddles keep the sand mass loosened and the bitumen, as a froth, escapes and floats to the surface.

It has been observed that as larger amounts of water are added to the bituminous sand during the heating and treating stage, the bitumen froth that floats to the surface upon flooding the treated sand with water becomes less and less frothy. Finally, when enough water has been added to the bituminous sand, during treatment, to raise the sum of the water and bitumen contents to about 30% by weight, no froth at all is formed upon flooding. On emptying the machine the separated bitumen is found lying under water on the layer of clean sand tailings at the bottom. Apparently increasing the water plus bitumen content of the bituminous sand charge in the mixer decreases the space in the mass for air to occupy till finally all air is excluded. When there is no air present there can be no formation of froth.

A more helpful way of considering the froth phenomenon is that in a system made up of bitumen, sand, water and air, energy relationships apparently demand that the bitumen envelop the air to form bitumen bubbles. It is because of this that the bitumen floats in the hot water separation process and recovery of the bitumen from the sand is possible.

Meeting of the bitumen and air under suitable conditions for forming a froth can take place in a variety of ways in separation plants. In our laboratory and large scale plants[2] sufficient water was added to the bituminous sand charge in the mixture to exclude all air. However, the displacement of the bitumen from the sand was not done in the mixer. Instead, a constant discharge of treated sand from the mixer was united with a circulating stream of plant water and the combined streams conducted into a large vessel filled with water. The froth appeared on the water in this large vessel. The froth was probably formed from air drawn into the large body of water by the plunging of the circulating stream into it.

Retention of Mineral Matter by the Separated Bitumen.

The bitumen froth retains some mineral matter from the silica sand, silt and clay from which it has been separated. In the case of separations in the simple mixing machine procedure it was found that the more air there was for froth formation and consequently the lighter the froth the more mineral matter there was retained. There seems little doubt, consequently, that it is the bitumen-air interface that holds the mineral matter.

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[2]Hot Water Separation of Bitumen from Alberta Bituminous Sands. K. A. Clark and D. S. Pasternack. Industrial and Engineering Chemistry, *24*, 1410, 1932.

Eleventh Annual Report of the Research Council of Alberta, 1930.

From analogy to what happens in flotation of metallic particles in ore concentration one would expect the bitumen froth to be selective in its choice of mineral matter retained. Such is the case. A comparison of the material held by the separated bitumen with the mineral aggregate of the bituminous sand shows a great concentration of coal and other non-silica particles. Also, the retained matter always has a much higher content of silt and clay than the original aggregate. There seems to be little preference shown for one size of quartz particle rather than another.

Since it appears to be the bitumen-air interface which holds the mineral matter, the obvious thing to do in the interest of sand-free separated bitumen is to reduce the amount of air available for froth formation. This is an effective measure, but cannot be carried too far because enough air to float the bitumen is necessary. Too little air means incomplete recovery of bitumen. Some retention of mineral matter is inevitable.

The Research Council has built half a dozen separation plants, large and small, and each one has differed from the others in the amount of mineral matter, on the average, which the separated bitumen retained. Separated bitumen from the laboratory plant used during 1928-1931 seldom had a mineral content above 5% (dry basis). The large plant in the North gave bitumen with a mineral content of from 10% to 20% (dry basis). The reason for these differences has always been a puzzle. Having arrived at the conclusion that retained mineral matter is related to the amount of air-bitumen interface in the froth, the inference would be that the differences were due to the variations in the opportunity for froth formation in the various plants. An investigation of the effect of various shapes and sizes of conduits for leading the circulating water and treated bitumen into the body of water on which the froth forms in continuous separation plants, as well as the velocity of this stream, would probably reveal interesting results.

Purification of Crude Bitumen.

Some refining operations will be required to eliminate the mineral matter retained by the bitumen in the primary separation process. The cleaner the separated bitumen, of course, the less strain there will be on the final purification equipment. Experience in the Research Council laboratory indicates that separation plants should give a crude bitumen containing less than 5% of mineral matter.

An obvious method for reducing the mineral matter in the bitumen is to settle it out. The main difficulty is that the temperature of the crude bitumen cannot be raised above 100°C on account of its water content and the viscosity at this temperature is still high. So settling is a slow process. By cutting the bitumen with ten to fifteen per cent. of an oil distillate the viscosity is greatly lowered and settling takes place rapidly. All sand particles can be removed leaving only very fine, clayey material. The addition of the distillate would not be objectionable since the bitumen must be passed through distillation equipment for working up into marketable products.

The crude bitumen also contains a high percentage of water—as high as 30%. However, once the gritty mineral matter is removed, there is no great difficulty about removing the water. It can be taken out by distillation operations well known to the oil refining industry.

EXAMINATION OF SOME FROST BOIL OCCURRENCES ON ALBERTA HIGHWAYS.

A stable subgrade is essential to good highways. If the earth grade goes out of shape, becomes soft and unable to hold up loads, or otherwise fails, the surface of the road is bound to fail too. In spite of the exercise of good engineering in the construction of the road grade, peculiar soil conditions are encountered which result in sections of unstable subgrade. Among these conditions are those which give rise to frost boils—spots along the highway which heave during the winter and turn soft in the spring when the frost leaves the ground. It is fairly obvious that the prerequisite to a decision about the proper remedy for a frost boil is a knowledge of the soil conditions giving rise to the trouble. During the summer of 1934 the soil conditions at five frost boil locations on our main highways were examined.

There are two conditions which must occur together to give rise to a frost boil. There must be a supply of water at not too great a depth below the surface of the road. Also, this water supply must be covered by a type of soil which is capable of raising water by capillary action into the zone of frost action. Further, the soil, while having pronounced capillarity must not be so fine grained that more than insignificant quantities cannot pass through it during some period of time like a week or a month. The heaving is caused by the growth of layers or lenses of ice in the soil. The surface is elevated by an amount equal to the thickness of the ice layers that have built up. When spring comes and the frost leaves the ground the ice layers turn to water. Then not only is the soil in a loose condition from the movement caused by the ice growths, but, in addition, the water from the melted ice is left in the loosened soil and softens it. The result at the surface of the road may be anything from an unstable, springy grade to a positive mud hole in which traffic becomes mired.

The growth of the ice layers from water drawn up from the water source follows from the capillary rise of water through the fine pore spaces of the soil and also from the fact that water when in the form of very fine filaments has a freezing point below the normal freezing point; how much below depends on how fine the filaments are, the finer the lower the freezing point. Thus when the soil temperature is below 32°F, water in the fine soil passages is still liquid. But there will be places in the soil where fair-sized spaces occur and fair-sized drops of water can form. The freezing point of these will be normal and they will turn to ice. These ice crystals then form the nuclei for ice accumulation. Water moves to them through the fine soil pores and freezes on reaching the surface of the ice crystal. By this means ice can build up as large masses or as numerous sheets. In the Lethbridge district where irrigation water forms a high water table and the road grades are composed of silty soil, trenches in subgrades where bad heaving occurs have shown as much as fifteen inches of ice layers. What happens when this ice melts in the spring and the water is released in the body of the subgrade can readily be imagined.

The freezing of damp or wet soil does not result in frost heaving. There may be an increase in volume due to the expansion of water on freezing, and careful measurement with a surveyor's level may demonstrate that the surface has risen. But it is a fairly uniform rise; not the sort of thing that is associated with the term "heaving." For heaving there must be a water reservoir from which moisture can be drawn continuously through overlying soil to a growing ice mass. If the soil over the reservoir is coarse grained like gravel or sand, heaving will not occur except under very unusual circumstances. The coarse pores do not draw water to an appreciable height, and the water in such pores

freezes when the soil temperature drops to the normal freezing point. Freezing conditions result simply in frozen soil. Nor is heaving likely to occur if the water reservoir is covered by clay. Although the clay has very fine pores and great capillarity, and although the water in these fine pores has a greatly lowered freezing point and so stays liquid when the soil temperature has dropped away below the normal freezing point, the soil offers such resistance to the passage of water that no appreciable quantity of it can be passed along from the water supply to an ice crystal. There may be growth of ice crystals, but only at the expense of moisture in the clay in the immediate neighborhood. The result is a drying effect on the surrounding clay soil and the net increase in volume is small. It is when the water reservoir is covered by silty soils that heaving takes place. These soils have pronounced capillarity, and do not offer so great resistance to water movement but that sufficient water can be passed through them to build up large ice accumulations.

Soil Classification.

The Bureau of Roads, Washington, has classified soils on the basis of their texture and their performance in highway subgrades. A very brief outline of the classification follows:[3]

Group A-1. Well-graded material, coarse and fine, excellent binder. Highly stable under wheel loads irrespective of moisture conditions.

Group A-2. Coarse and fine material, improper grading or inferior binder. Highly stable when fairly dry, likely to soften at high water content caused either by rains or by capillary rise from saturated lower strata when an impervious cover prevents evaporation from the top layer, or to become loose and dusty in long continued dry weather.

Group A-3. Coarse material only, no binder. Lacks stability under wheel loads, but is unaffected by moisture conditions. Not likely to heave because of frost nor shrink or expand in appreciable amounts. Furnishes excellent support for flexible pavements of moderate thickness and for relatively thin rigid pavements.

Group A-4. Silt soils without coarse material and with no appreciable amount of sticky colloidal clay. Has a tendency to absorb water very readily in quantity sufficient to cause rapid loss of stability even when not manipulated. When dry or damp presents firm riding surface which rebounds but very little upon the removal of load. Likely to cause cracking in rigid pavements as a result of frost heaving and failure in flexible pavements because of low supporting value.

Group A-5. Similar to Group A-4, but furnishes highly elastic supporting surfaces with appreciable rebound upon removal of load even when dry. Elastic properties interfere with proper compaction of macadam during construction and with retention of good bond afterward.

Group A-6. Clay soils without coarse material. In stiff or soft plastic state absorb additional water only if manipulated. May then change into liquid state and work up into interstices of macadam or cause failure due to sliding in high fills. Furnishes firm support essential in properly compacting macadams only at stiff consistency. Deformations occur slowly and removal of load causes very little rebound. Shrinkage properties combined with alternate wetting and drying under field conditions are likely to cause cracking in rigid pavements.

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[3]Subgrade Soil Constants. Their Significance, and Their Application in Practice. C. A. Hogentogler, A. M. Wintermyer and E. A. Willis. Public Roads, 12, p. 89, 1931.

Group A-7. Similar to Group A-6, but at certain moisture contents deform quickly under load and rebound appreciably upon removal of load, as do subgrades of Group A-5. Alternate wetting and drying under field conditions leads to even more detrimental volume changes than in Group A-6 subgrades. May cause concrete pavements to crack before setting and to crack and fault afterwards. May contain lime or associated chemicals productive of flocculation in soils.

Group A-8. Very soft peat and muck incapable of supporting a road surface without being previously compacted.

It will be noticed that frost heaving is given as a characteristic of Groups A-4 and A-5 soils only. This does not mean that heaving occurs in no other types of soil. It is possible for conditions, including the weather, to so arrange themselves as to lead to ice accumulation in soils of the other groups. But experience has shown that it is a Group A-4 or 5 soil that is the offending soil in most frost heave occurrences.

The Bureau of Roads has also devised a system of-soils tests and interpretation of test results for determining the group to which a soil belongs.

Soil Survey.

The procedure used for examining the soil conditions at frost boil locations on our highways was to make soil surveys. At each location stakes were set out along the ditch at 50-foot intervals extending some distance either side of the frost boil. At each stake a hole was bored with a soil auger to a depth of six feet. The nature and thickness of the soil layers passed through were recorded.

Similar observations were made regarding soil layers exposed in the side of the ditch above the level of the top of the bore hole. Holes at shorter intervals than 50 feet were bored where necessary to locate where some change in soil arrangement took place. Finally, the elevations of the tops of all the bore holes were determined as well as enough other elevations to allow of the making of a small topographical map of the road, ditches and adjoining land. Knowing the elevation of the tops of the holes and the soil layers and their thicknesses up and down for these elevations, it was a simple matter to plot a soil profile showing the arrangement of soil layers for a distance that included the frost boil occurrence. Samples of soil from the various layers were collected for examination and classification in the laboratory.

Soil Profiles at Frost Boils.

The soil profiles at the five frost boils examined are shown in Figure I. It should be mentioned that the vertical and horizontal scales to which these profiles are drawn are not equal. The vertical scale is much exaggerated. If a unit of length horizontally represents 50 feet, the same unit vertically represents 5 feet.

Profile I represents the soil condition found at a frost boil occurrence on the face of a hill on Highway No. 2, just west of the C.F.C.N. radio station about two miles east of Strathmore. An irrigation ditch crosses the road at the top of the hill and a bad boil occurs every spring about halfway down. The surface soil is a sandy loam belonging to Group A-2 in the soil classification. Below the surface soil comes a layer of silty A-4 soil. This is followed by a comparatively thin layer of clay with the silty soil below that again. But it will be noted in the profile that the clay layer is missing in the central part of the profile, and it is along the road grade over the stretch where the clay is

missing that the frost boil occurs. The water supply for the frost heaving comes from the irrigation ditch at the top of the hill. The water seeps down through the silty soil forming a water table that is just under the clay layer where it is present. No heaving occurs where the clay overlies the water-table, since the fine-grained, impervious clay prevents enough water passing upwards to give rise to any appreciable amount of ice accumulation. But where the clay is missing conditions are right for frost heaving. The silty soil draws water up into the body of the grade readily and in ample amounts for supplying the growth of masses of ice.

To remedy this frost boil it will be necessary to excavate the subgrade over the frost boil area down to the water table. Two procedures are then possible. The excavated silty soil can be discarded and gravel substituted, or clay can be secured from some neighboring source and the clay layer made continuous. The grade can then be restored with the excavated material.

Frost boil No. 2 occurs on Highway No. 1, about two miles north of Okotoks. The heave takes place on the brow of a hill. All the soil layers consist of silty, A-4 soils. The layer marked with crosses in the diagram has a light, sandy appearance in the field and is gravelly where it outcrops. Where it thins out and goes through the dip, it becomes an impervious hard-pan. This hard-pan basin holds the supply of water which causes the heaving.

The supply of water on which this frost heave depends could be eliminated by breaking up the bottom of the hard-pan basin. This could be done by the judicious use of some light charges of explosive placed in bore holes.

Frost boil No. 3 occurs on a flat a short distance south of No. 2. The road is carried across the flat on an embankment. Suitable conditions for frost heaving are obviously present. It is not so obvious, however, why the frost boil occurs where it does rather than in other places along the profile. Before the road was raised, trouble from frost heaving was general across the whole flat. Probably the spot located on the diagram is just a particularly bad one.

The placing of the road across the flat on an embankment of material not subject to frost heaving seems the only solution for the difficulty at this location.

Profile 4 was made at a frost boil occurrence on Highway No. 3, about six miles east of Pincher station. The road here is near the top of the descent into the valley of the Old Man river. The soil condition is very interesting. The lower part of the profile shows sand belonging to Group A-3 saturated with water ending abruptly against a wall of clay. A thin layer of clay caps the wet sand at the right of the profile. The sand and clay are overlain by Group A-2 soil. The boil occurs where there is no clay over the sand. The road crosses just the edge of the saturated sand mass, since bore holes on the opposite side of the road showed only clay beneath the surface soil.

A simple remedy by drainage would seem applicable to this situation. The road continues to the left on a down grade. The wet sand could be tapped readily at an elevation six feet or so below the water table by a trench in the ditch, and the water conducted away down hill. The porous sand should drain quickly and the water table be lowered sufficiently to remove the condition causing frost heave.

Profile 5 shows the soil conditions at another frost boil on Highway No. 3, about 3½ miles east of Pincher station. The road here is on a side hill cut along a slope rising to the north of the highway. No soil layers were found here. Instead, the clay soil changes fairly quickly into a silty soil and then back

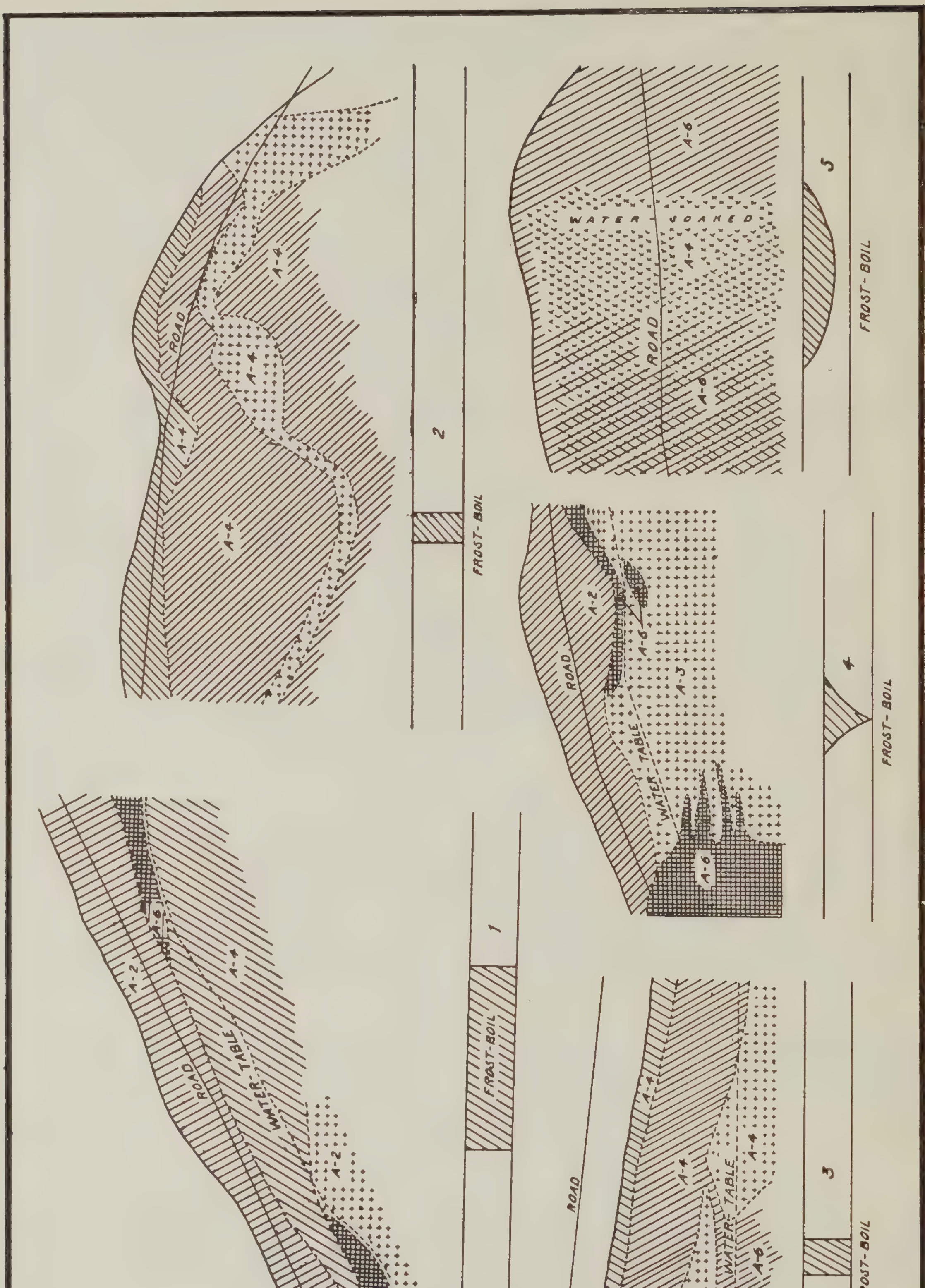

Figure V.—Road plan showing locations of frost boils and corresponding soil profiles showing the arrangement and nature of the soil layers. The vertical scale of the profiles is ten times as large as the horizontal scale, thus exaggerating the thickness of layers and the steepness of grades.

into a fairly clayey one again. The silty soil is water soaked above as well as below the ditch, and the frost boil occurs over this wet zone. Again it is just one side of the road that is affected. On the lower side, opposite the wet place, a six-foot bore hole revealed only clay.

It is possible that drainage alone would remedy this boil. A trench on the upper side of the road six or seven feet deep with drain tile at the bottom and back-filled with gravel, connected with a similar trench crossing the road at the centre of the affected area, would intercept and dispose of water seeping through the water-soaked silt core of the hill. The drains should be installed in any case. If not sufficient in themselves, the road grade would need to be excavated over the frost boil area and gravel substituted.

The work of the past summer is a modest beginning of the investigation of subgrade problems on Alberta highways. It is hoped that results of further studies may be presented in subsequent reports.

NATURAL GAS RESEARCH

BY E. H. BOOMER.

As has been the rule for the past few years, the work on gas research during the period under review has been on a reduced scale. In May, 1934, C. A. Johnson was appointed research assistant to re-open the research on gas solubilities in liquid hydrocarbons under a grant from the National Research Council of Canada. In October, V. Thomas was appointed by the University as a demonstrator in chemistry and research assistant on the oxidation of natural gas. At the same time, J. F. Badner was given a small problem on the corrosion of lead under high pressures of sulphuric acid. All these assistants are members of the graduate school in the University.

Considerable data was obtained on the solubility of purified Viking gas in three different petroleum fractions boiling in the hexane range. The chief results were to demonstrate the limitations of the apparatus and to show that investigations with pure liquids were necessary before dealing with complex fractions obtainable from Turner Valley napthas. The apparatus has been improved and redesigned in several particulars, and is now capable of giving unambiguous and precise results. Work has commenced on pure cyclo-hexane. Pentane, hexane, heptane and methyl-cyclo-hexane are available for examination.

It was desirable to extend the oxidation research beyond the limitations imposed by the original work on one mixture, 8.5% oxygen in gas, and plans were made for a new method allowing the use of any mixture up to the theoretical proportions for methyl alcohol formation. Much work was done on improving the analytical methods. Considerable apparatus had to be designed, constructed and assembled. The danger of explosions in air or oxygen and gas mixtures under pressure made it essential that the utmost care be used in the design and operation of the apparatus. Preliminary work has resulted in some modifications of design, and although the apparatus is not wholly satisfactory as yet, it is believed that the worst difficulties have been overcome. Preliminary results with mixture containing the stoichiometrically correct proportions of air and natural gas for the formation of methyl alchol, and using a copper catalyst, have been disappointing. The efficiency as measured by yield of useful products is much less than found in previous work with lower oxygen concentrations. The catalyst does not suppress explosions entirely, and permits carbon deposition in the reaction chamber. Nor does copper appear to catalyse the desired reactions under these conditions to the extent expected. Interesting relations between this work and the known properties of gas explosions under pressure have been evident from the first, and are suggestive of lines of attack on the problem. It is planned to improve the apparatus and method in some particulars and investigate more promising catalysts than copper.

The investigations on the corrosion of lead have their origin in observations made upon lead gaskets in high pressure sulphuric acid scrubbers used to remove sulphur compounds from Viking gas supplied to Edmonton. This procedure has been found necessary in this laboratory since the Northwestern Utilities commenced odorizing the gas. Lead is normally quite resistant to sulphuric acid, but the gaskets in the scrubbers mentioned were rapidly corroded. The cause has been traced directly to the products of the reaction between sulphuric acid on the organic sulphur compounds in the gas. Sulphur dioxide is

liberated in these reactions and in some manner not yet clear, causes a comparatively rapid corrosion of lead. This is true at atmospheric pressure as well as at high pressures. The investigations have covered various concentrations of acid at pressures from 1 to about 230 atmospheres, with and without the addition of sulphur dioxide and other sulphur compounds.

A list of publications from this laboratory on natural gas researches, for the years 1930 to 1935 inclusive, follows.

PUBLICATIONS.

Theses submitted to the University of Alberta by graduate students of the University. These are available for reference in the University Library:

On the hydrogenation of bitumen from the bituminous sands of Alberta. Preliminary experiments on the liquefaction of characteristic Alberta coals by hydrogenation at high pressures and elevated temperatures. A. W. Saddington, 1931.

The pyrolysis of Alberta natural gas. P. E. Gishler, 1931.

The catalytic decomposition of ethyl alcohol and catalytic reactions of water gas mixture under pressure. H. E. Morris, 1931.

The reaction in mixtures of hydrogen and the oxides of carbon at high pressure. Preliminary experiments on the solubility of methane in hexane. G. H. Argue, 1932.

On the liquefaction of carbonaceous materials by hydrogenation. J. Edwards, 1933.

The direct oxidation of natural gas at high pressure. J. W. Broughton, 1933.

A study of the effect of concentration, pressure, temperature, and added sulphur compounds on the corrosion of lead in sulphuric acid. J. F. Badner, 1935.

Papers published in the Canadian Journal of Research:

The formation of ethane in the catalytic decomposition of ethyl alcohol. E. H. Boomer and H. E. Morris. 2:384-387, 1930.

On the hydrogenation of bitumen from the Alberta bituminous sands. E. H. Boomer and A. W. Saddington. 2:376-383, 1930.

On the hydrogenation of bitumen from the bituminous sands of Alberta, II. E. H. Boomer and A. W. Saddington. 4:517-539, 1931.

Reactions of ethyl alcohol on nickel-chromium catalysts. E. H. Boomer and H. E. Morris. 6: 471-484, 1932.

Decomposition of Ethyl Alcohol Over Some Poly-Component Catalysts. E. H. Boomer and H. E. Morris. 10:743-758, 1934.

The Hydrogenation of Alberta Coals. I. Preliminary Experiments on Suspension Media and Catalysts with Three Coals. E. H. Boomer and A. W. Saddington. 12:285-839, 1935.

Hydrogenation of Alberta Coals. II. Comparative Data on 13 coals of various ranges and two suspension media Tetralin and Liquid Petrolatum. E. H. Boomer, A. W. Saddington and J. Edwards. Vol. 13, July, 1935, pp. 11-27.

Papers in proof to appear in the Canadian Journal of Research, Vol. 13, 1935.

Hydrogenation in a Tetralin Medium.

I. Destructive Hydrogenation of Bitumen and Pitch. E. H. Boomer and J. Edwards.

II. Destructive Hydrogenation of Coal with Tetralin and with a Mixture of Related Compounds as Media. E. H. Boomer and J. Edwards.

III. Destructive Hydrogenation of Cellulose & Wood. E. H. Boomer, G. H. Argue and J. Edwards.

IV. Destructive Hydrogenation of Grain Screenings. E. H. Boomer and J. Edwards.

LIST OF PUBLICATIONS
OF
RESEARCH COUNCIL OF ALBERTA
EDMONTON, ALBERTA

ANNUAL REPORTS OF COUNCIL

No. 3 (for the calendar year 1920); pp. 36. **Price 5 cents.**

No. 5 (for the calendar year 1921); pp. 86. **(Out of print.)**

No. 8 (for the calendar year 1922); pp. 64. **Price 35 cents.**

No. 10 (for the calendar year 1923) with 4-color map of Alberta coal areas; pp. 76. **Price 50 cents.** Map No. 6 only, **15** cents.

No. 12 (for the calendar year 1924); pp. 66. **Price 35 cents.**

No. 16 (for the calendar year 1925); pp. 65. **Price 35 cents.**

No. 20 (for the calendar year 1926); pp. 53. **Price 25 cents.**

No. 22 (for the calendar year 1927); pp. 49. **Price 25 cents.**

No. 24 (for the calendar year 1928); pp. 53. **Price 35 cents.**

No. 25 (for the calendar year 1929); pp. 65. **Price 35 cents.**

No. 26 (for the calendar year 1930); pp. 76. **Price 35 cents.**

No. 27 (for the calendar year 1931); pp. 53. **Price 35 cents.**

Nos. 28, 29 & 32 (for the calendar years 1932-1934): pp. 90. **Price 35 cents.** These three annual reports on fuel investigations, geological surveys, road materials studies, soil surveys and natural gas researches carried out under the auspices of the Council, were prepared each year, but not published owing to financial reasons. They are here included in one volume, published in 1935.

REPORTS—FUELS

No. 10A (1923); COMBUSTION OF COAL FOR THE GENERATION OF POWER, by C. A. Robb. **(Out of print.)**

No. 14 (1925); pp. 64. ANALYSES OF ALBERTA COALS, with 18 maps and 2 charts. By E. Stansfield, R. T. Hollies, and W. P. Campbell. **Price 25 cents.**

REPORTS—ROAD MATERIALS

No. 18. THE BITUMINOUS SANDS OF ALBERTA, by K. A. Clark and S. M. Blair.

Part I—Occurrence, pp. 74. **Price 25 cents.**

Part II—Separation, pp. 36. **Price 25 cents.**

Part III—Utilization, pp. 33. **Price 25 cents.**

REPORTS—SOIL SURVEY DIVISION

No. 23 (1930); PRELIMINARY SOIL SURVEY ADJACENT TO THE PEACE RIVER, ALBERTA, WEST OF DUNVEGAN, by F. A. Wyatt and O. R. Younge; pp. 33 and colored map. Scale 1 inch to 4 miles. **Price 50 cents.**

No. 31 (1935); PRELIMINARY SOIL SURVEY OF THE PEACE RIVER-HIGH PRAIRIE-STURGEON LAKE AREA, by F. A. Wyatt; with colored map. Scale 1 inch to 4 miles. **Price 50 cents.**

REPORTS—GEOLOGICAL SURVEY DIVISION

By Dr. J. A. Allan, Professor of Geology, University of Alberta.

No. 1 (1919); pp. 104—A summary of information with regard to the mineral resources of Alberta.

No. 2 (1920); pp. 138+14. Supplements the information contained in Report No. 1.

No. 4 (1921); GEOLOGY OF THE DRUMHELLER COAL FIELD, ALBERTA; pp. 72, and 6-color map (Serial No. 1). **(Out of print.)**

No. 6 (1922, Part I); GEOLOGY OF THE SAUNDERS CREEK AND NORDEGG COAL BASINS, ALBERTA, by J. A. Allan and R. L. Rutherford; pp. 76 and 2-color map (Serial No. 2). **(Out of print.)**

No. 7 (1922, Part II); AN OCCURRENCE OF IRON ON THE NORTH SHORE OF LAKE ATHABASKA, by J. A. Allan and A. E. Cameron; pp. 40; two maps (Serial Nos. 3 and 4.) **(Out of print.)**

No. 9 (1923); GEOLOGY ALONG BLACKSTONE, BRAZEAU AND PEMBINA RIVERS IN THE FOOTHILLS BELT, ALBERTA, by J. A. Allan and R. L. Rutherford; pp. 48, and 6-color map (Serial No. 5). **(Out of print.)**

No. 11 (1924); GEOLOGY OF THE FOOTHILLS BELT BETWEEN McLEOD AND ATHABASKKA RIVERS, ALBERTA, by R. L. Rutherford; pp. 61, and 8-color map (Serial No. 7). One inch to two miles. **Price 75 cents.**

No. 13; GEOLOGY OF RED DEER AND ROSEBUD SHEETS, by J. A. Allan and J. O. G. Sanderson. Two geological maps in 8 colors. Scale, one inch to three miles. Serial No. 8 Red Deer Sheet and No. 9 Rosebud Sheet. Five structure sections. **(Report in preparation.)**

Map No. 10 (1925); GEOLOGICAL MAP OF ALBERTA, by J. A. Allan. In 14 colors. Scale one inch to 25 miles. **(Out of print.)**

No. 15 (1926); GEOLOGY OF THE AREA BETWEEN ATHABASKA AND EMBARRAS RIVERS, ALBERTA, by R. L. Rutherford; pp. 29 and 3-color map (Serial No. 11). One inch to two miles. **Price 50 cents.**

No. 17 (1927); GEOLOGY ALONG BOW RIVER BETWEEN COCHRANE AND KANANASKIS, ALBERTA, by R. L. Rutherford; pp. 46 and 9-color map (Serial No. 12). Scale one inch to one mile. **Price $1.00, or map alone 50 cents.**

No. 19 (1928); GEOLOGY OF THE AREA BETWEEN NORTH SASKATCHEWAN AND McLEOD RIVERS, ALBERTA, by R. L. Rutherford; pp. 37 and 3-color map (Serial No. 13). Scale 1 inch to 3 miles. **Price 50 cents.**

No. 21 (1930); GEOLOGY AND WATER RESOURCES IN PARTS OF PEACE RIVER AND GRANDE PRAIRIE DISTRICTS, ALBERTA, by R. L. Rutherford; pp. 80 and 6-color map (Serial No. 14). Scale 1 inch to 4 miles. **Price $1.00.**

No. 30 (1934); GEOLOGY OF CENTRAL ALBERTA, by J. A. Allan and R. L. Rutherford; pp. 41 and 10-color map (Serial No. 15). Scale 1 inch to 10 miles. **Price $1.00.**